SPACE FLIGHTS

SPACE FLIGHTS

Mohan Sundara Rajan

National Council of Educational Research and Training

March 1973
Phalguna 1894

Price: Rs. 3.40

PUBLISHED AT THE PUBLICATION UNIT, NIE CAMPUS, SRI AUROBINDO MARG, NEW DELHI-16, BY M.C. VERMA, SECRETARY, NATIONAL COUNCIL OF EDUCATIONAL RESEARCH AND TRAINING, AND PRINTED AT CASLON PRESS, KAROL BAGH, NEW DELHI-5

Dedicated
to the memory of

Nicolaus Copernicus

Foreword

THE National Council of Educational Research and Training brings out supplementary reading material for school boys and girls on topics which may interest them, but which may not fall strictly in the school curriculum. The present volume belongs to this category. It is written by an author who has taken a considerable amount of interest in the topics under discussion. The views expressed and the statements made are those of the author.

It is hoped that this volume, which is copiously illustrated, would provide interesting reading material.

S. V. C. AIYA
Director, NCERT

New Delhi-16
2nd February, 1973

Preface

This book seeks to bring out the spirit of adventure and courage in man's attempts to unravel the mystery of space. The triumph and tragedy in the adventures of the space pioneers, particularly in the Gemini and the Soyuz series, are treated as a continuous story of man's undaunted will to master a new environment, after millennia of gravity-bound existence. His step-by-step attempts to build an orbiting laboratory in space, which will revolutionise life on the earth are also explained bringing out the hazards of weightlessness.

However, the space age is not just a string of brave deeds. Equally important and interesting is the scientific aspect of the new adventure. The rich harvest of scientific data, revealed by spacecraft, is therefore scanned in detail rather than space technology or its application. The region near the earth, including radiation zones, the atmosphere and new phenomena above it, are described in the light of the data being obtained by satellites.

This is followed by an account of the manned and unmanned probes to the moon, with a separate chapter on the results of the exploration. Both the Apollo and the Luna series are extensively analysed.

The next part explains the various inter-planetary probes. The new world beyond the solar system forms the subject of the concluding chapter.

I thank Dr Y. V. Somayajulu, Assistant Director, Space Research Section, Radio Science Division, National Physical Laboratory, New Delhi, and Dr B. K. Nayar, Executive Secretary, Indian National Science Academy, New Delhi, for their valuable comments on the manuscript.

Thanks are also due to the United States Information Service; the U.S.S.R. Information Department; the Director, Indian Institute of Astrophysics, Kodaikanal; the Director, Vikram Sarabhai Space Centre, Thumba, and the Director, Photo Division, Ministry of Information and Broadcasting, for permitting the use of photographs obtained from them in this publication.

MOHAN SUNDARA RAJAN

Contents

1

IDEAS AND INVENTIONS

I always find it hard to convince people that the present state of affairs is not the end of the road. Nothing is more certain than that the future will be greatly different from the present.

FRED HOYLE

Ideas and Inventions

From time immemorial, man has gazed at the sky in wonder. He has devised ingenious methods to understand the heavenly order. In ancient Egypt, the sun-clock seems to have been in regular use by 1000 B.C.

In the second century A.D., Ptolemy said that the earth was the centre of the universe, but maintained that none could cross the equator! A Syrian, called Lucian, wrote a story of a group of people who were blown to the moon. In the fifth century, the noted astronomer in India, Aryabhatta, suggested that the earth rotates on its axis and revolves round the sun. In the seventh century, Brahmagupta gave the circumference of the earth, which later proved to be nearly correct.

In China, gunpowder was invented, and around 900 A.D. rockets were also in use. It is on record that, in 1232, the Mongols used rockets against a Chinese city.

In the fifteenth century, the great genius Leonardo da Vinci was fascinated by the flight of birds and designed several devices like the glider and helicopter, to fly. His approach was highly scientific.

An original thinker of the Renaissance period was a Polish astronomer, Nicolaus Copernicus (1473-1543). Born at Torun in Poland he proposed that the sun is in the centre of the solar system. This book, the result of thirty years of hard work, opened up a new era in the

history of astronomy. It was a victory for scientific thought. Poland of his days was conducive for the flowering of new ideas. Yet, it needed a lot of courage to propose an idea that was different from the ancient texts.

Nicolaus Copernicus

Johannes Kepler (1571-1630) refined the observations of the sky and gave his famous laws. He said the orbits of the planets are not circular but elliptical. He also wrote science fiction, in which he envisaged a trip to the Moon.

Kepler's contemporary Galileo Galilei (1564—1642) turned the telescope towards the sky and saw the moon, the sun, the four major moons of Jupiter and the phases of Venus.. His ideas caused an uproar in an age which believed in a closed universe of Heaven, Earth and Hell. Those around him, including several professors, turned a blind eye to his discoveries and he was forced to recant his views. Galileo also proved that the weight of the objects does not by itself cause any difference to the speed of their fall. In a vacuum, both a feather and a coin would fall at the same time.

The Falling Apple and After

A great intellectual after Galileo was Isaac Newton (1642—1727). The famous fall of the apple set him thinking on the forces that hold celestial objects in their paths. He gave the laws of motion and gravitation, which provide the basis for rocketry and satellite orbits today. His famous law of Universal Gravitation explains the movement of various bodies in the solar system.

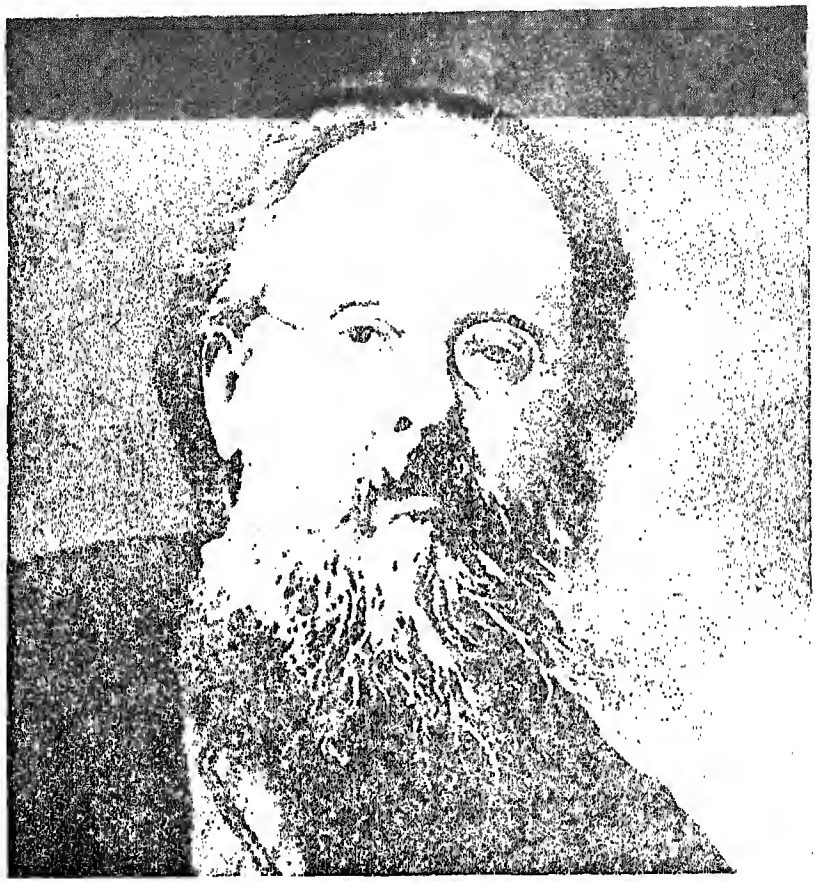
In 1784, manned balloons were used for the first time to observe the weather. However, it was disappointing to note that man could not survive even at a height of eight kilometres. The idea of travelling in space received a set-back. But by then, a device which later enabled man to go in space had come into use, though for a different purpose. That was the rocket used for hurling fire into the enemy camps. Hyder Ali and Tippu Sultan of Mysore used them effectively against the British. The idea soon travelled to Europe and several armies in the West were soon using rockets. But no one imagined that rockets could go up like a balloon.

That idea occurred to the famous French fiction writer Jules Verne. His work *From the Earth to the Moon*, published in 1865, envisaged practically all the technical problems of space travel and tried to solve them too. He proposed a giant gun to launch his moon travellers.

The years following Jules Verne's novel saw some unique discoveries of great relevance to space travel, but not in those times. In 1873, Maxwell propounded the theory of electro-magnetic waves. Later, Marconi demonstrated the propagation of radio waves. Hertz proved that Maxwell was right in his ideas and generated the electro-magnetic waves.

Tsiolkovsky—the Pioneer

Among the many people influenced by Jules Verne's ideas was a Russian school teacher, Konstantin Tsiolkovsky (1857—1935). Although he was born of poor parents and had no formal education, he became a teacher of physics by his own efforts. It was he who proved mathematically that a rocket can take man into space and predicted the use of liquid fuels to propel rockets. He anticipated the mixture of liquid oxygen and liquid hydrogen or kerosene to propel rockets. He pointed out the advantages of having different stages in a rocket or different engines being clustered together to a rocket. He even envisaged the the need for growing plants to get oxygen and food for the astronauts on long journeys. In 1903, when the Wright brothers successfully flew in their airplane, Tsiolkovsky published his main findings



Konstantin Tsiolkovsky

in astronautics. A few years earlier, he had stated some 800 equations of great importance to space travel. He envisaged man's entry into space in 2017 A.D. His dream became a reality 56 years earlier. In 1935, he told his people in a radio broadcast that many among those who heard him, would live to see man's conquest of space. Tsiolkovsky thought of space travel as an instrument of change in the very life of the people of the world. He pointed out that man is using

only a fraction of the sun's energy and eventually he is bound to build towns and cities orbiting the earth thousands of kilometres away. He said, the earth is the cradle of man, but one cannot remain in the cradle for ever.

A contemporary of Tsiolkovsky was Nikolai Kibalchich (1853—81). He became a revolutionary at a young age and started making bombs. He was accused of trying to derail the train of the Czar, and was sentenced to death. The 27-year-old lad, while awaiting the sentence in his jail, wrote on rocketry and said that ships heavier than air could fly one day with the help of gun-powder. His plea for a scrutiny of his ideas by a team of scientists was rejected. For 36 years, no one thought about it, until after the October Revolution.

An important man who has contributed much to the development of rockets was Robert Hutchings Goddard, a Physics professor in America. He said that a liquid fuel would be better than the powder used to power the rocket. On March 16, 1926, he launched the world's first liquid fuel rocket. It flew a distance of only 56 metres, but laid the foundation for space travel. He received as many as 214 patents covering all aspects of rockets.

Another person who was devoted to space travel was Germany's Hermann Oberth. In 1923, he published a small book on rockets and space travel. He envisaged space stations with men on board. His writings popularised space travel, and rocket societies were formed in several countries.

Work on perfecting rockets went on in Russia and Germany. During the Second World War, hundreds of experts worked at Peenemunde in Germany, on the shores of the Baltic, to produce the missile known as the V-2. The first V-2 rocket was test flown in 1942. In the Soviet Union, a team of engineers led by Korolev was working on rockets.

After the War, some German rocket experts led by Dr. Wernher Von Braun, went to America, while some of their colleagues went to the Soviet Union.

The quiet work soon yielded good dividends. On October 4, 1957, the Soviet Union began the era of space flights by launching the first spacecraft, Sputnik 1. Four months later, on January 31, 1958, the U.S. Satellite, Explorer-1, was orbited.

2

ADVENTURES IN THE NEW SEA

There can be no thought of finishing, for aiming at the stars, both literally and figuratively, is the work of generations, but no matter how much progress one makes, there is always the thrill of just beginning.

ROBERT H. GODDARD

The Pioneers

In Jules Verne's novel, a cat and a squirrel went up on a journey to the moon, before the brave men of fiction. Tsiolkovsky spoke of testing animals in space to gather data for man. In the Soviet Union, research was done in the late 1940s on animals to know the effect of abnormal vibrations, noise, pressure and temperature. Tests were made in chambers simulating the conditions in space. In the early 1950s, dogs were sent up to an altitude of a hundred kilometres. The tests indicated that man can survive in space.

The world's first space traveller was a dog, named Laika. She travelled in Sputnik 2, launched on November 3, 1957. Data on her physical conditions were obtained by radio signals. She was provided with food, water and oxygen. Though her pulse rate went up at launch, it came down later.

The next phase of testing was recovery from orbit. It was done in 1960. Two dogs, Strelka and Belka, were sent into space and successfully brought back. Later, they gave birth to several healthy pups. The spacecraft also carried insects, plants and micro-organisms. White rats and black mice were also sent along with the dogs and recovered. The hair of black mice changed colour. Fruit flies (Drosophila) were also sent up, as radiation effect on their progeny has been well studied. By observing their off-spring, the effects of cosmic radiation can be known.

Dogs, Veterok and Ugolyok which made a 22-day orbital flight on Cosmos--110

A few weeks before man's first space flight, two more dogs safely ıpleted their journey around the earth.

rtles Win the Race

Several other living beings went round the moon to. Aboard Soviet unmanned satellite, Zond-5, which circled the moon and re- ıed to earth in 1968, were turtles, mealworms and bacteria, besides ıt seeds, such as wheat and barley. Turtles can stand considerable ss. They resist ultra-violet radiation, as well as the deficiency or ɔlus of oxygen. On return, the turtles were very active. They had . the race to the moon! They lost about 10 per cent of their body

weight, but three weeks after their return, certain chemical changes were found in their liver.

For evaluating the effect of weightlessness on the human body, bull frogs were used. In 1970, the Americans sent up two bull frogs, aboard a satellite. These frogs have a structure similar to man's to feel the sense of balance.

A few months before the first American astronaut orbited the earth, a chimpanzee was launched into space. He was recovered in good shape. The five-and-a-half-year-old chimp operated different levers as indicated by coloured lights. Shortly before man landed on the moon, the Americans orbited another monkey. He munched his full quota of food and also experienced a dream in space. This was indicated by sensors attached to his brain. But after a week, he became restless. He did not care to earn the extra banana pellets, which would pop out on completion of a complicated job. He ignored the green lights asking him to do certain jobs. On the ninth day in space, his performance declined. He was brought down ahead of the planned thirty-day schedule. He died twelve hours after splash-down.

Animals will continue to scout for man in exploring other planets and outer space. They may also accompany him on such journeys. They would even serve him as sensing objects, to warn him of certain deficiencies developing in the spacecraft.

Gagarin—the First Man in Space

The first man to travel in space was Yuri Gagarin, a Russian fighter pilot. At the age of 27, he became the world's first cosmonaut. The great moment came on April 12, 1961. Gagarin took off from Baikonur in a three-stage rocket, called Vostok-1. The first orbital flight looping the earth lasted only 108 minutes. But what a fantastic flight it was! An ancient dream of man came true. A new era opened.

Gagarin proved that man could stand a space journey, which includes the fiery launch and the difficult re-entry through the dense layers of the earth's atmosphere.

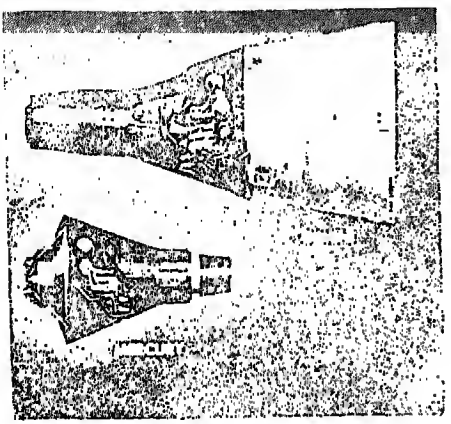
A few weeks after Gagarin's historic adventure, an American completed a sub-orbital flight lasting 15 minutes and 22 seconds. He was Alan B. Shepard. On May 5, 1961, Shepard in a Mercury spacecraft went up to 184 kilometres. A notable feature was the use of manual controls by the astronaut. Just before the splash-down, he jumped out, but he was quite safe. Two months later, another American astronaut, Virgil Grissom, completed the testing of sub-orbital flight lasting a little over fifteen minutes.

Yuri Gagarin

Meanwhile, the Russians had made further progress. In August 1961, Gherman Titov stayed in space much longer. He orbited the earth seventeen times (as against one by Gagarin) and his was the first day-long orbital flight. He was also the first to take a cine camera into space and begin the practice of observing geographical features of the earth and its cloud patterns.

Spaceship Vostak

The Americans were now ready for achieving an orbit. On February 20, 1962, John Glenn orbited the earth three times at a height of 260 kilometres in a Mercury spacecraft, named Friendship-7.



Mercury and Gemini

Three months later, Scott Carpenter also did three orbits. He went a little higher than Glenn to 267 kilometres. He however overshot by 320 kilometres, while landing.

Then came the world's first simultaneous flight of two manned spacecraft. In August 1962, the Soviet cosmonaut, Andrian Nikolayev, set up a new record, by orbiting the earth 64 times, in nearly four days. His colleague, Pavel Popovich, who did 48 orbits, passed at one time within five kilometres of Nikolayev's spacecraft.

For the Americans, Walter Schirra in Sigma-7 increased the orbital duration. He achieved five orbits as against three by John Glenn.

There were two highlights in space in 1963. Astronaut Gordon Cooper did the final flight in a Mercury spacecraft, increasing the number of orbits to twenty-two. The Soviet Union ended the series of Vostok flights, but with a new achievement. It sent a woman into space.

A Woman in Space

She was then known as Valentina Tereshkova. In June 1963, she was in space for 70 hours and 50 minutes. She completed 48 orbits covering two million kilometres. At times, she passed within five kilometres of Vostok-5, in which her colleague, Valery Bykovsky, was circling. Bykovsky was in space for about five days completing 81 orbits, the longest till then.

Valentina was only 26 when she flew in space. The daughter of a small farmer, she worked in a textile mill. She attended evening classes and became a cotton technologist. She was eager to fly and became a good parachute jumper. After seeing a space film, she decided to become

a cosmonaut and underwent rigorous training. After her flight, she married the cosmonaut Nikolayev.

For more than a year after Valentina's flight, no space flight was reported from the Soviet Union. Apparently, they were preparing a new type of spacecraft, called Voskhod. In October 1964, they launched three men in one such new type of spacecraft. Also for the first time, a doctor was included in the crew. He was Boris Yegorov. His colleagues were V. Komarov and K. Feoktistov. The space trio completed 16 orbits.

Valentina Tereshkova

Leonov Walks in Space

Meanwhile, Soviet engineers were preparing for yet another novel experiment. In March 1965, cosmonaut Alexei Leonov became the first man to 'walk' in space. He and his Voskhod's commander, Belyayev, performed a unique feat, though they were in space for just 26 hours and 2 minutes.

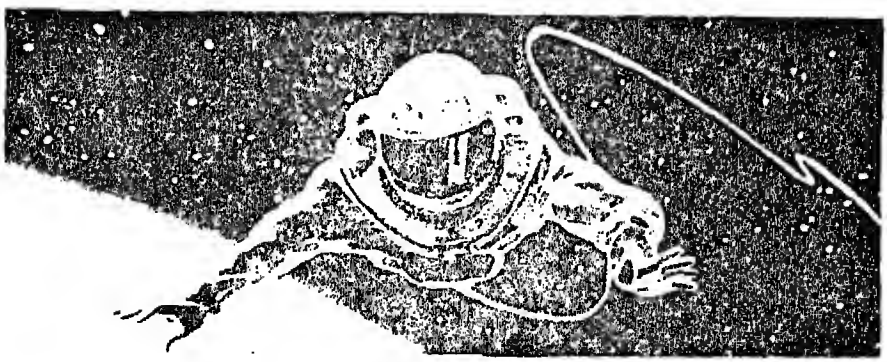
Walking in space is really floating in a vacuum. The only link with the ship is by a life-line. This is an important aspect of the conquest of space by man. For he has to come out of the safety of his spacecraft to repair a spacecraft, or to link two spacecraft or to rescue a cosmonaut in trouble.

As the continents revolved below, the two cosmonauts were travelling at a speed of about 27,200 kilometres an hour, at an average height of 493 kilometres above the earth. Alexei Leonov checked his space suit, oxygen and pressure. After spending 10 minutes in the air-lock inside

the spacecraft, Leonov emerged into the void. He floated in space for 10 minutes, spending in all 21 minutes in the vacuum. At one stage, he pulled himself up with some force, by the life line connecting him to the spacecraft. But he avoided collision with the space craft by softening the impact with his hands. He said that there was no uneasiness but added that space was no place for pleasure trips. His pulse rate was 135 beats a minute, but he removed, without difficulty, a camera from outside the spacecraft. The commander of the ship, Belyayev, watched him on TV. He could have gone out to his aid, in case there was a need.

It was an extensive preparation that enabled Leonov to do the space walking. In the preceding year, he

Alexei Leonov



A Drawing by Leonov

cycled over 1,000 kilometres, did a lot of running and skiing, besides undergoing special training.

What struck Leonov was the beauty of the earth. Himself a painter, he was elated to see the beauty of the Black Sea, the Volga, the Urals and the Siberian rivers against the black canopy.

Belyayev and Leonov found certain anomalies in the automatic control of their spacecraft for landing. Hence, they were allowed to use manual control.

The Gemini Series

Manual control played a key role in American space flights. They evolved a new type of spacecraft, called Gemini, meant for two astronauts. The first two in the series were unmanned. Gemini-3 took off in March 1965, shortly after Leonov's walk in space, with Virgil Grissom and John Young. It was the first spacecraft to change its orbit.

As for the Russians, there were no reported flights for the next two years (till 1967), while the Americans completed ten Gemini flights.

In the next flight, Gemini-4, Edward White walked in space. He became a human satellite orbiting the earth at 192 kilometres above the Pacific Ocean. He was approaching the Californian coast at a speed of 28,000 kilometres an hour. White and James McDivitt who was also in Gemini-4 extended the experience of weightlessness to four days.

A unique feature of this exercise is a hand-held self-controlling unit, called 'the gun' to enable the astronaut to move around. White was out in the void for 21 minutes. He said 'the gun' was quite useful to move about at will. After the gun's supply of gas was exhausted, he continued with his life-line cord, but it created problems for the commander in controlling the spacecraft. As White returned, the hatch door did not lock normally. Metals behave strangely in the vacuum in space.

There was no sensation of falling. Nor was there any big sensation of speed.

White took the first picture of a spacecraft in orbit taken from outside. He and McDivitt showed that photographs of the earth could

A View of the Earth from Space

reveal surprisingly clear details.

The Gemini flights that followed White's walk in space developed the techniques of changing the orbit, closely flying together (rendezvous), joining one spacecraft to the other (docking) and walking and working in space over longer periods.

In Gemini-5, Gordon Cooper and Charles Conard were in space for eight days (as against four in the case of Gemini-4 flight). They also successfully moved with the second stage of the rocket which launched them. It was in this mission that an engineering marvel called fuel-cell was introduced. It produces electircity out of hydrogen and oxygen, with water for the astronauts as a by-product.

In the next Gemini flight., astronauts Walter Schirra and Thomas Stafford waited to be launched but the Agena target rocket, which they were due to catch up later, exploded! It was then decided to send Gemini-7 astronauts in orbit first to be met in space by Gemini-6. Frank Borman and James Lovell took off in Gemini-7. Both the manned vehicles were brought within 30 centimetres of each other in space. Gemini-6 achieved the first successful guided re-entry, with the help of computers. While descending, Schirra surprised everyone by playing a harmonica from space! Gemini-7 stayed on to set up a new record of being in space for 14 days.

Docking Two Spacecraft

Next came the world's first docking, i.e., joining of two spacecraft. Neil Armstrong, who later became the first man on the moon, and David R. Scott chased a target rocket and docked with it. But there was trouble. The combined spacecraft began to tumble violently. They had to undock and make an unscheduled re-entry, out of range of any tracking station. They used the on-board computer and splashed down in the Pacific instead of the Atlantic, as scheduled earlier.

Then came Gemini-9. In 1966, Astronaut Eugene Cernan took a record 'walk' in space outside the craft, lasting for over two hours. He walked for one and one-third orbits of the earth, far exceeding the earlier record of just 21 minutes by Edward White. However, he could not use his new back pack which contained propulsion fuel, oxygen and

a 38-metre line for extensive manoeuvring. His visor got fogged, apparently because of the sudden change in temperature, as the spacecraft went from light to darkness. The commander of the spacecraft, Thomas Stafford, ordered him to get back. They could not however dock with a target vehicle, as a shroud on it was sticking out like an angry alligator.

The experiments continued. Gemini-10 astronauts, John Young and Michael Collins, first docked with a target rocket, called Agena-X, and then with another target called Agena, VIII. An experimental instrument was recovered from the latter target, after it had been in space for four months.

Conrad and Gordon in Gemini-11 set up new space records. For the first time, they chased and docked with a target rocket on their very first orbit of the earth, in just 94 minutes after take-off. Conrad fired the Agena rocket, with which they had docked, to raise the combined spacecraft to a record height of 1,360 kilometres. The Gemini spacecraft and the Agena satellite were joined by a 31-metre long rope. Several photos were taken, particularly of the southern hemisphere, including India. Standing in the open hatch of the spacecraft, Gordon took photos of three star constellations in ultra-violet light. But Gordon could not do the scheduled space walk, as exhaustion and perspiration forced him back after 44 minutes. He could only pick up a cosmic ray equipment, mounted outside the Gemini.

New Records

The last Gemini mission in November 1966, was the best in the series, though it had to be postponed twice because of minor defects. The Gemini-12 astronauts, James Lovell and Edwin Aldrin, did all the assigned tests. Aldrin who holds a doctoral degree in astronautics, set up many records. These included the longest single space walk of 2 hours and 90 minutes and the longest period (5 hours and 27 minutes) of exposure to space conditions. He thrice came out of the spacecraft. A heartening feature was that there was no fatigue, as experienced by the earlier space-walkers. The splash-down was also the most accurate to date.

They were the first to photograph a solar eclipse from outside the earth's atmosphere. Lovell guided his spacecraft under the shadow caused by the moon hiding the sun, while Aldrin snapped it for six seconds. Astronauts also kept date with a vapour trail let off by a French rocket over the Sahara and photographed it in an experiment to study the winds sweeping the desert.

Ten weeks after the Gemini series ended on a hopeful note, tragedy struck the space programmes of both the United States and the Soviet Union.

Tragedies

It was January 27, 1967. The place was Cape Kennedy. A new type of spacecraft, Apollo, with three men on board, was to be tested. Atop the giant Saturn rocket were astronauts Gus Grissom, Edward White and Rogar Chaffee. Suddenly someone on the ground heard the word 'fire' from the astronaut cabin. There was stunned silence, followed by agonising moments. It was all over in a few minutes. A faulty electrical wire had given off a spark and there was one hundred per cent oxygen inside.

In April 1967, the Russians tried a new space vehicle called Soyuz, meaning union. It was their first manned spaceflight after an interval of two years, but it proved tragic.

Cosmonaut Komarov completed eighteen orbits of the earth in Soyuz-1 and was preparing to re-enter the earth's atmosphere. The retro-rockets were successfully fired but the straps of his parachute got mixed up and he could not make a soft-landing. The fatal accident occurred at about seven kilometres above the ground.

As Komarov's mortal remains were interred in the Kremlin wall, Yuri Gagarin was almost in tears, not knowing that he too would leave his colleagues soon. It happened within a year, on March 27, 1968. The first man to fly in space was snatched away by the indiscriminate hand of death. It was again an accident but not in space. He was killed in an aircrash, together with Col. Vladimir Seregiv in an airfield near Moscow at the end of a training flight. A commission of inquiry disclosed that they took off on a normal flight in a two-seater trainer.

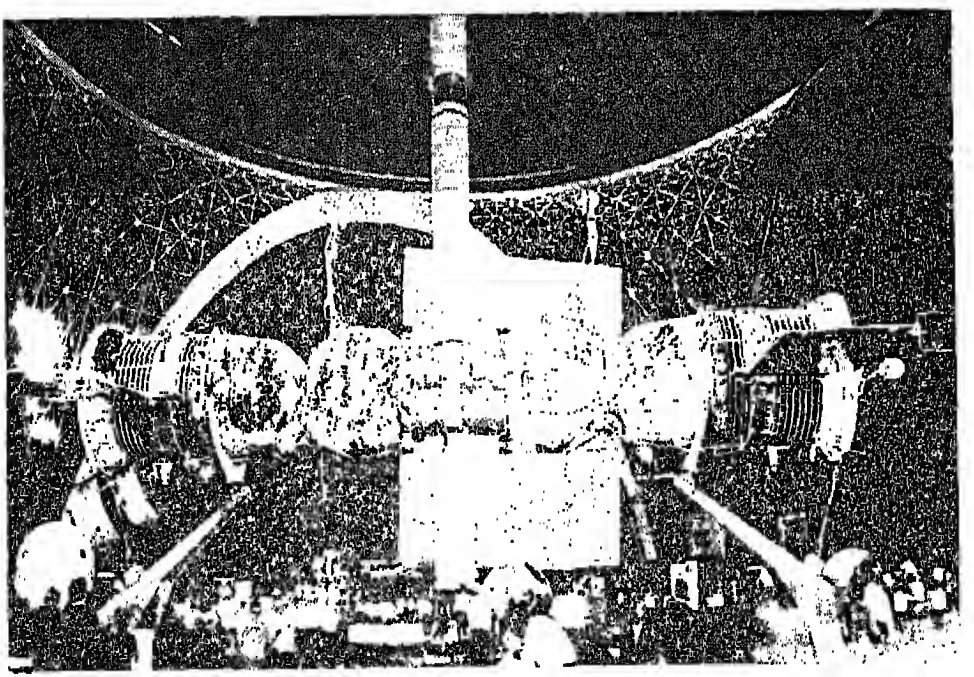
The Adventure Continues

Gagarin was an optimist. His example of courage and perseverance inspired others. Eighteen months after the tragedy, another attempt was made with Soyuz and it was successful. On October 26, 1968, Soyuz-3 with Cosmonaut Beregovoi was launched. He was 47 and was the oldest man to fly in space. A day earlier, an unmanned Soyuz-2 was launched. During his very first orbit, Beregovoi approached Soyuz-2 within 200 metres. Both automatic and manual controls were used. He completed 61 orbit in four days. He was given a hero's welcome. His success gave the Russians new confidence. Within eleven weeks, the world's first experimental laboratory was set up in space by Soyuz-4 and Soyuz-5.

A fortnight before the trail-blazing flight of cosmonaut Beregovoi, American astronauts came back to the launch pad, after the tragic flash fire in 1967. For the first time, three astronauts, Walter Schirra, Don Eisele and Walter Cunningham, went in space in a single spacecraft. It was the first manned test of an Apollo spaceship in earth orbit.

A Laboratory in Space

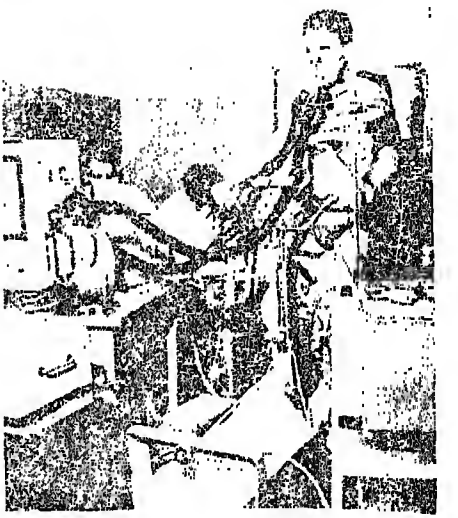
THE Soviet Union achieved yet another first in space technology, when it linked up two manned spacecraft in space. When Soyuz-4 and Soyuz-5 were joined together in January 1969, two cosmonauts switched from one spacecraft to the other from outside.



A Manned Orbital Station, displayed at an exhibition in Moscow

First Soyuz-4 was launched with Shatalov on board. Next day, Soyuz-5 was lofted into space, with three cosmonauts, Volynov, Khrunov and Alexei Yeliseyev. A day later the two spacecraft were linked. Cosmonauts Khrunov and Yeliseyev came out of Soyuz-5, "walked" in space and then entered Soyuz-4 to join Shatalov. The next day they landed. Volynov on Soyuz-5 continued his lonely journey and came back the following day.

A unique aspect is the greater role given to manual control in accomplishing this task. The two ships were brought together from a distance of 1,000 kilometers. At the beginning, the automatic correcting systems were switched on, until they were 100 meters apart when the ship commanders changed over to manual control. The link-up was televised to earth. Once the spaceships were mechanically coupled, electrical circuits were also established. Then the cosmonauts could talk to one another on internal telephone as well.



Shatalov, Commander of Soyuz-4, undergoing training

Shortly after the link-up, Khrunov and Yeliseyev prepared themselves to change their vehicle. It was later stated that it was easier to don a space suit in zero-gravity rather than on the ground. They had no difficulty in floating from one spacecraft to the other. They said the most practical way out in space was to use one's hands and hold on to the firm rails as a means of support. There was no fogging of their visors and Khrunov was able to disconnect a camera and fix it again, besides checking the operation of the control jets on the spacecraft. The two

cosmonauts spent about one hour outside the spacecraft. The two spacecraft flew in the coupled position for 4 hours and 35 minutes. The two ships separated after three orbits of joint flight.

The crucial transfer of crew did not take place through any tunnel inside the spacecraft but was accomplished from outside by the cosmonauts walking in space. It would become essential for man to emerge out of his spacecraft to construct laboratories in space. Rescue of cosmonauts or repair of spacecraft require the exit of man from his spacecraft. Even the normal change of crew might be done by this method. The long-term significance of this link-up is the scope it gives to assemble parts of bigger spacecraft in space. There is thus no need to employ huge rockets to bring up all the weight in one launch. Smaller rockets could launch a big station part by part and men could join them in space.

The experimental space station had four living compartments with a total volume of 18 cubic metres. The temperature was within 15° to 25°C, relative humidity 40-70 per cent, and the carbon dioxide content inside did not exceed 1 per cent.

It is interesting to note that the cosmonauts observed the 24-hour day, even though during one orbit the day has 16 sunrises! The quick succession of 45 minutes of days and nights would be bewildering! Soviet psychologists were of the view that the 24-hour rhythm of physical processes ensures man's highest physical and mental activity and raises his stamina.

There were still problems in manned space flights. In particular, the area of action for man and the machine was yet to be demarcated. Towards this end, further efforts were made.

Shortly before this experiment, the Americans successfully orbited the moon in the Christmas of 1968. By the time the Russians tried their next Soyuz series in October 1969, the U.S. astronauts had landed on the moon.

A Space Trio

"What is this place?" By the time one aboard a spacecraft asks this question, the vehicle would have moved some 40 kilometres! What

then are the implications of bringing three spacecraft in different orbits close to one another with the minimum use of fuel? A group flight was achieved in the Soyuz-6, -7 and -8 mission, to know the problems.

In October 1969, Soyuz-6 was launched with Georgy Shonin and Flight-Engineer, Valery Kubasov. The next day, Soyuz-7 went up with three cosmonauts, Commander Filipchenko, Engineer Veadislav Volkov, and V. Gorbatko, a Research Engineer. A day later, the third Soyuz was put into orbit. The two-man crew consisted of Vladimir Shatalov and Alexei Yeliseyev, Flight Engineer. It was for the first time that seven cosmonauts were in space simultaneously.

One of the aims of this mission was to test the improved design of the Soyuz spacecraft. They carried additional fuel needed for such extended activity. It was claimed that they could soar to a height of 1,300 kilometres above the earth, as against the usual 200 kilometres altitude. In all, 31 different joint manoeuvres were carried out. The three spacecraft changed their orbits several times and many of the alterations were made by the cosmonauts themselves. At times the spacecraft came within 457 metres of each other. They were trying to control the spacecraft, as the pilots control aircraft.

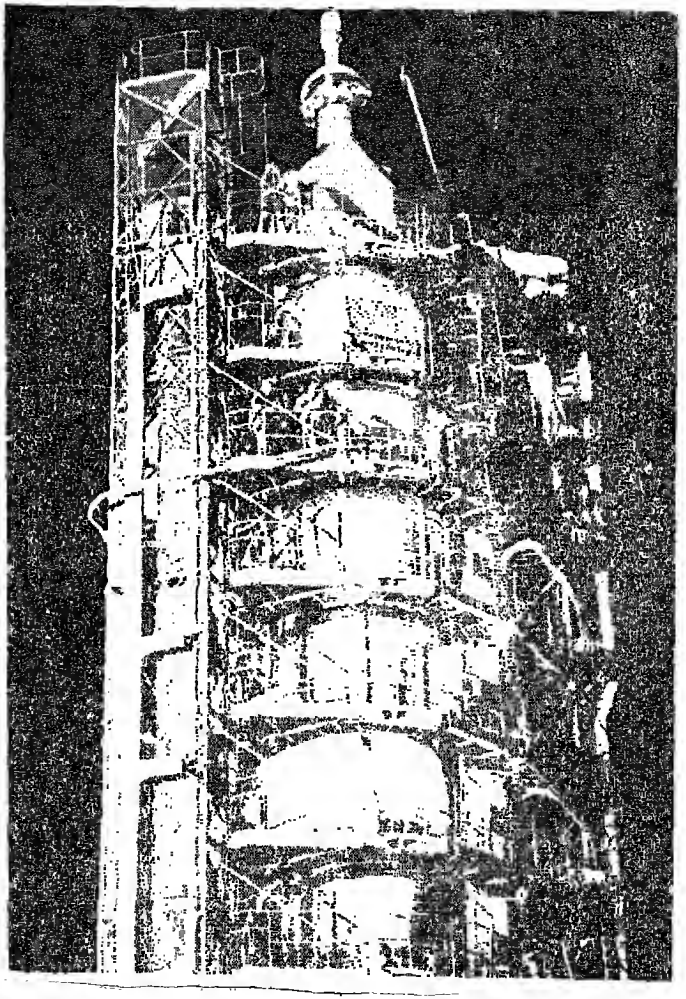
Special tests were made to evaluate the activity of the cosmonauts as a group. Psychologists say that a man's behaviour in a group is different from his individual actions.

Welding Metals in Space

A novel experiment by the space trio was a special kind of welding metals in space. This method takes advantage of the vacuum above the atmosphere as it is difficult to create a perfect vacuum in laboratories. The more the vacuum, the firmer and more accurate becomes the welded joint. Only vacuum could remove all obstacles for joining two elements, when they are brought very close to each other. Such a process can do wonders. It can combine steel and glass, silver and quartz, metal and non-metal. Indeed, under high vacuum, metals can spontaneously weld.

Welding aboard Soyuz-6 was done in the orbital compartment and was remotely controlled from the recovery compartment, by Kubasov.

The trio also made observations of the earth and the stars, useful for weather forecasting, mineral prospecting and measuring the snow cover.



Soyuz-9 at the Launch Pad

Soyuz-9 Sets Up a Record

A new record in manned space flight was set up by the Soyuz-9 cosmonauts, Commander Andrian Nikolayev and Flight Engineer Vitaly Sevastianov, in 1970. They were in space for 18 days, from June 1 to 19, longer than the 14-day record of Borman and Lovell in Gemini-7.

The cosmonauts took three to four days to develop new movement habits. Their pulse rate, respiration and heart beats adapted themselves to the zero-gravity situation.

The cosmonauts lost weight during the flight, even though they had a good appetite. They were not very thirsty, but drank plenty of water. Twice a day they did special physical exercises in order to keep themselves ready to face the return of gravity on the muscles. Despite a heavy programme of work aboard the spaceship, the cosmonauts found time to play chess with the ground crew. The game lasted six hours and ended in a draw.

A [illegible]
nauts [illegible]al and biological studies. The cosm[illegible] adapted well to th
space[illegible]itions of weightlessness. They had retained their appetite an
port.[illegible]ty to work and sleep. Their heartbeats had stabilised after five c
orbits.

'Saly Then the busy programme of experiments began. It was a round
O'clock schedule and the cosmonauts took turns for resting. As man
craft 140 experiments were carried out.

ed ab
and N **ed Experiments**

spacec An important experiment was multispectral photography. The co
180 mauts photographed the same area of their country in different ways
of th area was observed simultaneously by an aircraft flying in formatio
dockin Salyut at about 8 kilometres, and by another plane at a still lowe
linke ude, all in a verticle line.

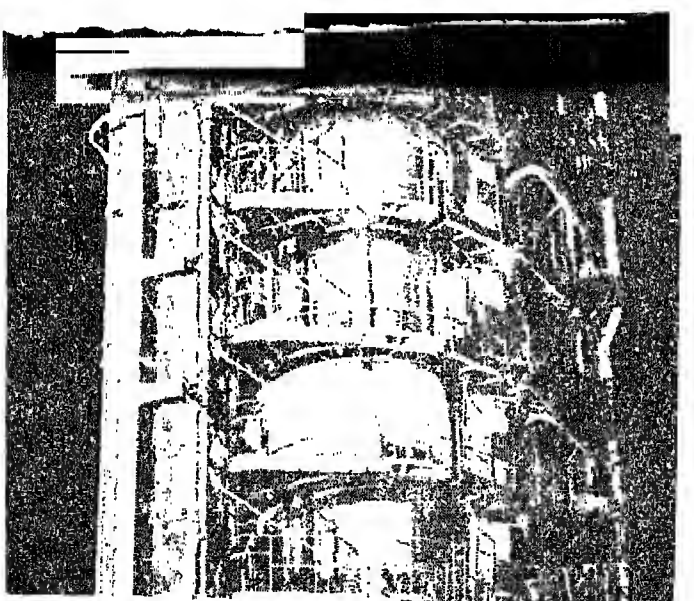
has The cosmonauts observed weather conditions in different parts o
and earth, including cyclones, dust storms and cold waves. Some o
his br observations were compared with those made by weather satellites
mon[illegible] [illegible]observation of [illegible]egorov said that the rendezvous and docking led to a considerable emotional load on the cosmonauts. The joint

flight of the Soyuz-Salyut complex lasted only 5 hours and 30 minutes. The two ships separated and Soyuz-10 soft-landed.

The experiment acquired significance in view of a statement by Academician Boris Petrov that near-space is the main arena of manned flights at the present stage of the Soviet space programme.

Soyuz-11—Triumph and Tragedy

Those who forecast that the Soyuz-Salyut experiment had ended too soon for some unknown reason were proved wrong. Soyuz-11 was launched on June 6, 1971, with Georgy Dobrovolsky, Vladislav Volkov and Viktor Patsayev. After a chase lasting 25 hours, they caught up with the giant Salyut on June 7. Then they transferred themselves through a passage. The aims of the mission were to check and test the on-board systems; to try out both automatic and manual means of navigating the station; to study the geological and geographical objects



Salyut-Soyuz Complex— the latest in the step-by-step progress towards building a space laboratory

of interest on the earth, like the atmosphere, snow and ice-cover and to study the physical characteristics of space.

The maximum distance of the Soyuz-11-Salyut complex from the earth was 282 kilometres and the minimum distance 259 kilometres. Its period of revolution was 89.7 minutes.

The space station looked like a big cylinder. It was four metres across and 20 metres long. It weighed 25 tons. Its capacity was 100 cubic metres. Though it was in space, the temperature inside ranged between 22 ' C and 17° C.

Shortly after their entry into the huge space station, the cosmonauts closed down their shuttle ship. Salyut was equipped with vacuum cleaners, books, refrigerators and water heaters. It was the world's first manned orbital station, though the Soviet descriptions referred to it as a prototype space station.

Their first week in space was spent more in orienting themselves to the new conditions of zero gravity. They were mostly engaged in medical and biological studies. The cosmonauts adapted well to the conditions of weightlessness. They had retained their appetite and ability to work and sleep. Their heartbeats had stabilised after five or six orbits.

Then the busy programme of experiments began. It was a round-the-clock schedule and the cosmonauts took turns for resting. As many as 140 experiments were carried out.

Varied Experiments

An important experiment was multispectral photography. The cosmonauts photographed the same area of their country in different ways. One area was observed simultaneously by an aircraft flying in formation with Salyut at about 8 kilometres, and by another plane at a still lower altitude, all in a verticle line.

The cosmonauts observed weather conditions in different parts of the earth, including cyclones, dust storms and cold waves. Some of their observations were compared with those made by weather satellites.

Their observation of outer space was done with the help of special instruments. One of them was outside the spacecraft. Different stars

were studied. Moreover, protons, neutrons and gamma rays were also monitored. Special aerials of different shapes studied the effect of the electrons on radio signals.

Inside their spacecraft, they cultivated several types of higher vegetation including cabbage and onion. A new nutrient solution was given to the plants. Many of them sprouted.

Special Costumes

Perhaps the most interesting part of their experiment was the way they fought the mysterious zero gravity environment. They donned special costumes to simulate terrestrial gravitation so that the skeleton and the muscles received near-normal pressure. They reported that the costumes were convenient. They performed special exercises aboard their spacecraft for more than four hours a day. They used a 'moving track' to retain the habits of walking and running.

On June 24, the cosmonauts crossed the 18-day record in space, set up by the Soyuz-9 team. A Soviet medical expert significantly observed that the Salyut group would then on be taking a step into the unknown

The Heroic Trio of Soyuz-11, who were found dead after a record-breaking 24-day odessey in space (From the left) Viktor Patsayev, Georgi Dobrovolsky, and Vladislav Volkov

with each new day. Their marathon flight continued. The world watched them anxiously.

Then on June 30, when they separated and began their journey home, just thirty minutes before landing, there was a rapid drop of pressure within the descent vehicle, which led to the sudden death of the cosmonauts. The spacecraft itself soft-landed and all the three men were found dead, strapped in their seats. The drop in pressure was confirmed by later analysis. It was stated to be due to a faulty sealing.

Shock and Sorrow

A wave of shock and sorrow spread throughout the world. The three men were hailed as "martyrs in the cause of knowledge". The ashes of the heroes were interred in the Kremlin Wall as a mark of high honour. The setback did not however dampen the will of the pilot-cosmonauts of the Soviet Union. They knew the risks and they were willing to pay the price to advance man's thrust into space. In an open letter, the pilot-cosmonauts expressed their determination to go ahead.

Soviet scientists hold that the stations of the Salyut type would pave the way for creating independent, permanent settlements, with a micro-world of their own. These are likely to be flying mini-planets created on the pattern of the earth. The scientists believe that the earthly crops will become a permanent feature of long-distance space travel. Another significant indication of their future plans was a Tass report that transport spaceships will fly periodically from cosmodromes, approach and dock with orbital stations. Tass said a 'winged spaceship' looks very promising. This shows their plans to devise re-usable spacecraft and bring about a change in the cost and mode of operating in space.

In the words of Academician Petrov, new flights into space and the building of new manned orbital stations of the Salyut type, lie ahead. "Undoubtedly, larger and more complex, multi-purpose and specialised manned space-stations will be built".

Soyuz-Apollo Link-up

The era of competition between the space powers seems to be

over. American astronauts and Soviet cosmonauts will meet in space in 1975. The year, an American Apollo and a Soviet Soyuz will be linked up, 270 kilometres above the earth. Two or three Americans and two Russians will be in spacecraft linked together for two days and transfer from one ship to the other through an airlock device on the Apollo's nose. The airlock is needed because the Apollo has a pure oxygen atmosphere while the Soyuz has nitrogen and oxygen under sea level pressure. The crew would stay in the airlock for two and a half hours. After the docking, the two crews would separate and descend to a lower orbit and remain there for eleven more days. There are also plans to link an Apollo with a Soviet Salyut space station in the late seventies.

3

SPACE—NEAR AND FAR

When you can measure what you are speaking about and express it in numbers, you know something about it.

LORD KELVIN

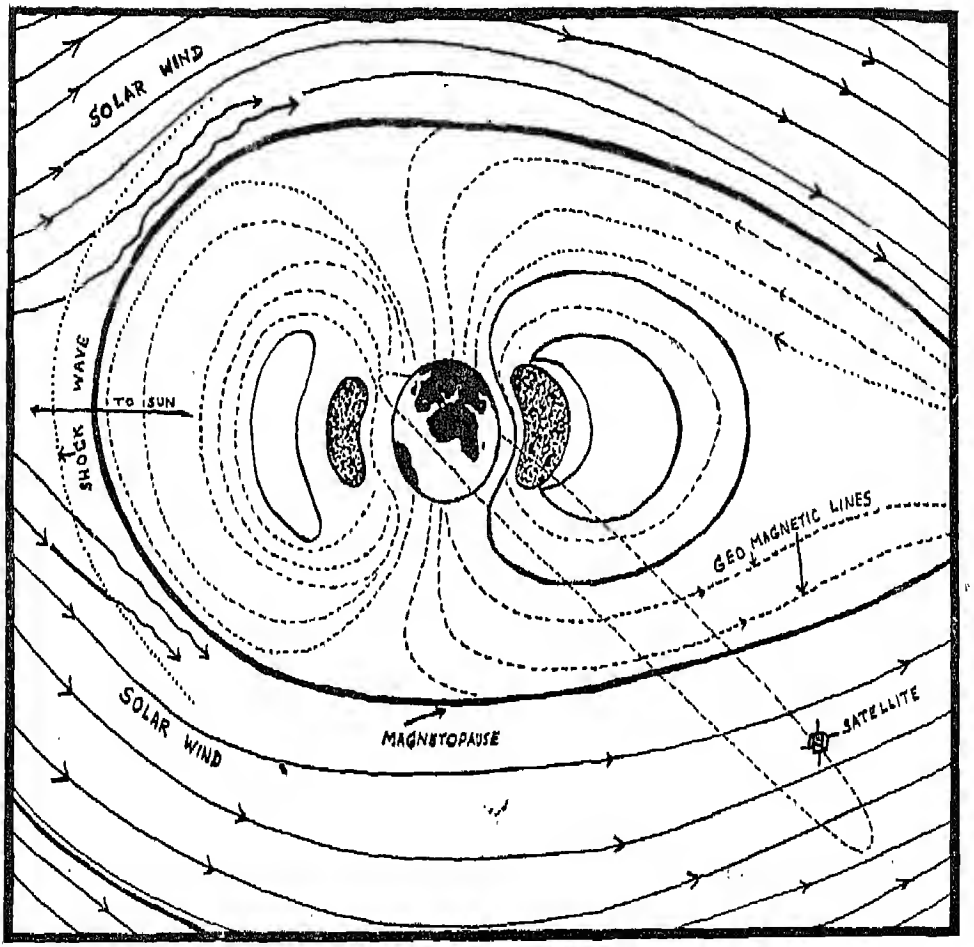
The Magnetic Envelope

WHILE man tested his ability to stay and work in space, unmanned satellites revealed to him a new world, in the space near the earth.

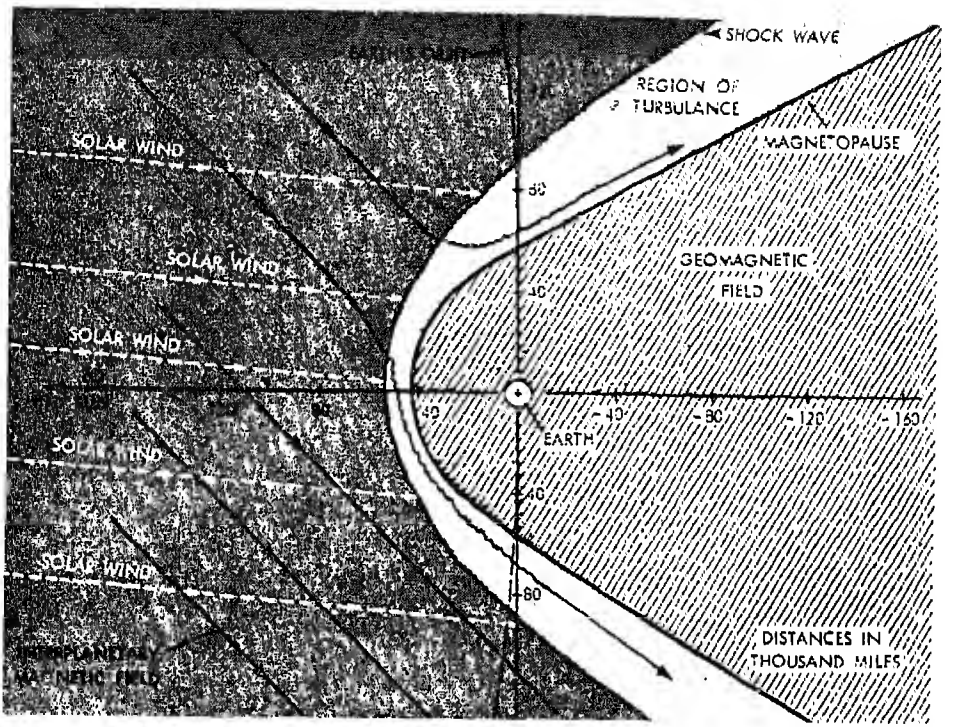
One of the fundamental but puzzling facts recorded by unmanned space probes is the solar wind—the wind of hydrogen that blows throughout the solar system at a fantastic speed of 400 kilometres per second. It takes four days to reach the earth.

Long ago, Kepler suggested that some mysterious force from the sun turns the tails of comets away from the sun. In 1959, this 'force' or 'wind' was confirmed by Luna-I and -II and later by Mariner-2.

The solar wind is like the blast of a rocket. It is ionised (electrified) hot gas, composed of low-energy charged atomic particles, comprising chiefly protons (hydrogen nuclei) and helium. Unlike the wind we feel, the solar wind draws out parts of the sun's magnetic field along with it and forms what is known as inter-planetary magnetic fields. As the sun rotates on its axis every 27 days the solar wind and magnetic fields drawn along, get twisted like water from a rotating lawn sprinkler. These magnetic fields considerably screen the earth from cosmic rays from outside the solar system. The distance covered by the solar wind ranges from twenty astronomical units to 100 astronomical units (an astronomical unit is the distance between the sun and earth, viz., 150 million kilometres).



The Magnetic Envelope Surrounding the Earth. It diverts the solar wind and protects our planet. Satellites in elongated orbits, passing in and out of the magnetosphere, indicate its boundary- Note also the radiation belts surrounding the earth.

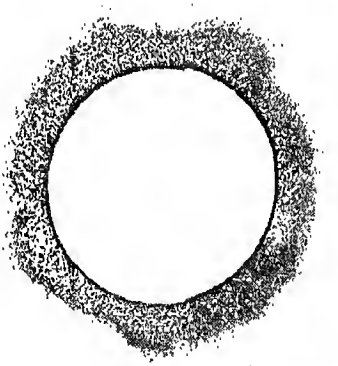


The solar wind which 'blows' continuously and the geo-magnetic field

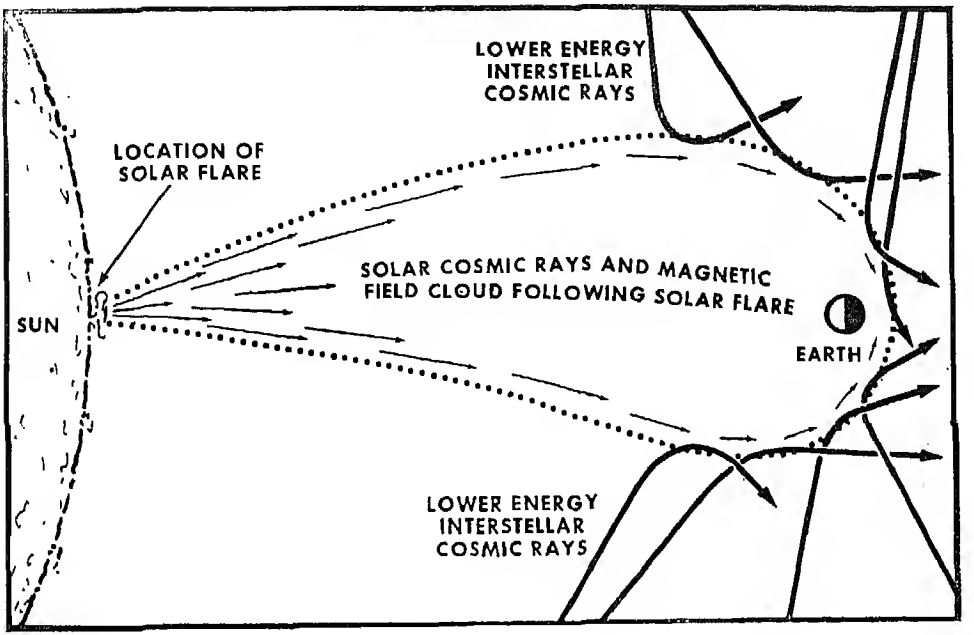
The solar wind confines the earth's magnetic field in a cavity known as magnetosphere. The solar wind curves around the magnetosphere. The boundary of the magnetosphere on the sunward side is about 64,000 kilometres from the earth. On the night-side, the magnetic field tapers off into a tail. As the solar wind strikes the magnetosphere at supersonic speed, a shock wave is formed which diverts the solar wind to flow away from the magnetosphere. Experiments on earth have proved the formation of a shock wave, whenever the speed of a body is more than that at which its medium, like air or water, can transmit sound. The unmanned U.S. satellite Explorer-18 detected the

shockwave about 84,000 kilometres from the earth on the sunward side, some 20,000 kilometres beyond the boundary of the magnetosphere. The region in between is called the zone of turbulance, where energy particles fluctuate.

The tail of the magnetosphere is elongated on the night-side. The magnetosphere begins at a 100-kilometre altitude and its influence was detected at five million kilometres by Pioneer-6. The Soviet Mars probe is reported to have detected the magnetic tail at 20 million kilometres Its diameter is about 5,12,000 kilometres.



Solar Corona photographed during the Solar Eclipse on March 7, 1970.



Solar Flares

There are two halves in the tail, separated by a thin neutral sheet of low magnetic strength. Another interesting finding is that the low energy electrons emitted by solar flares move in the magnetic tail towards the earth from the night-side. The constituents of the solar wind flow backwards towards the earth, to sustain the radiation belts surrounding the earth.

In order to study the shape, energy and the direction of the earth's magnetosphere, the Apollo astronauts launched mini-satellites to orbit the moon. The idea is that these satellites would pass in and out of the earth's magnetosphere.

The Soviet Union launched two satellites, Prognoz-1 and Prognoz-2, in April and June, 1972 to study the sun and its effects on earth. Their maximum distance from the earth is 2,00,000 kilometres and minimum about 950 to 400 kilometres. The unique advantage of their orbits

is that they can observe the sun, beyond the frontier of the earth's magnetosphere. This enables the study of changes in the solar wind, X-ray and gamma ray radiation from the sun, its radio emission and solar cosmic rays. The satellites have a special memory device to record all the data for transmission to earth. The study will help in forecasts of possible solar flares (sudden outbursts of charged particles into space). They could be dangerous to spacecraft and men going into space.

The radiation belts within the magnetosphere surrounding the earth were also discovered by satellites. The first unmanned American satellite Explorer-1 in 1958 discovered the radiation belts. They are called Van Allen radiation belts, after the scientist mainly responsible for it. Subsequent space probes have refined our ideas about this strange and interesting phenomenon.

It would be more realistic to call them radiation zones rather than belts. The inner zone begins at an altitude of 400 kilometres over Brazil and 1,300 kilometres over the East Indies and extends up to 6,400 kilometres above the equator. It is not uniform above all places. The outer zone which envelopes the inner zone, extends further to 64,000 kilometres. These boundaries are not definite. They change over a period of time. The two zones differ in the intensity of the charged particles. While it is relatively constant in the inner zone, it varies even from hour to hour in the outer zone.

The zones consist of electrically charged particles. Some of them are called protons (nuclei of hydrogen and positively charged) and some others, electrons (which are negatively charged). Their energies vary widely. Geneally speaking, the inner zone is dominated by protons, while the outer zone is noted for electrons.

The magnetosphere and the Van Allen radiation belts inside it act as a reservoir for storing solar flare energy. Whenever the magnetic field is disturbed, the trapped particles are squeezed out into the upper atmosphere, like flowers shaken from a tree. The stored energy is released in bursts called 'substorms', which disturb the upper atmosphere, often causing radio blackout.

Whenever the charged particles of the sun manage to crash through the earth's magnetic field at its weakest points viz., the polar regions,

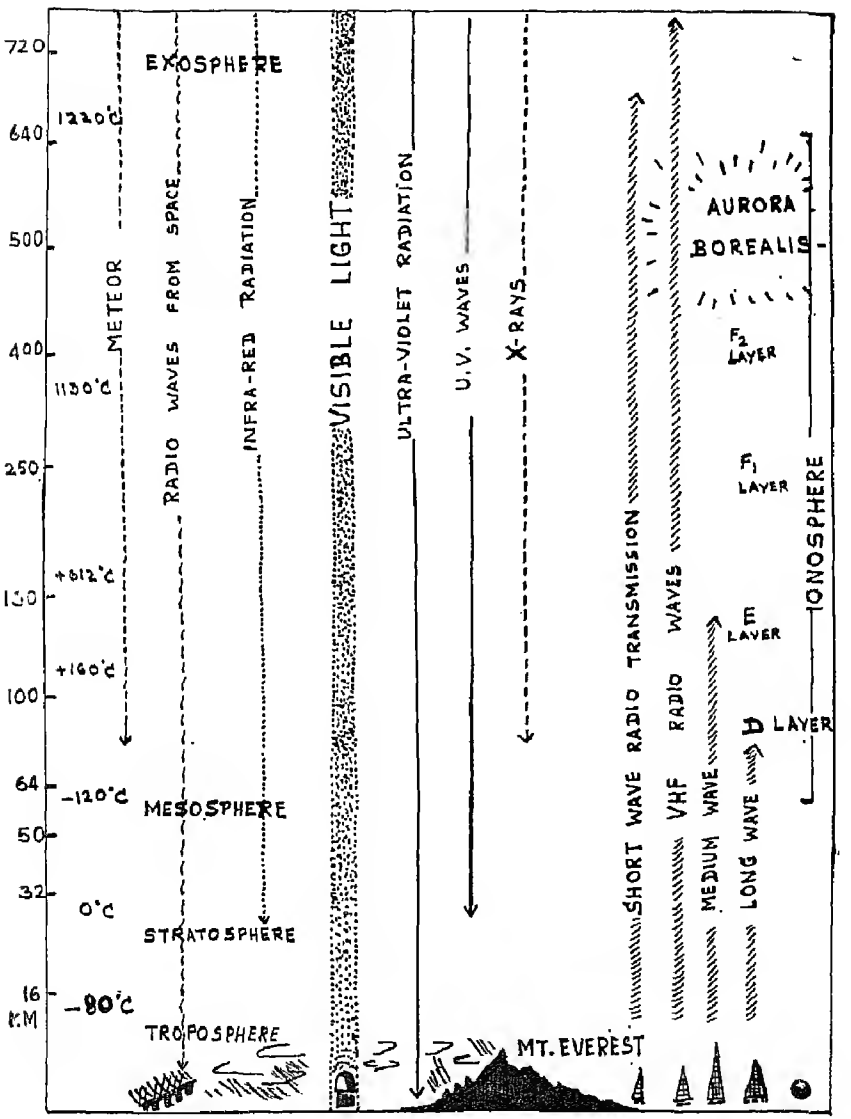
and penetrate the atmosphere, they produce polar aurorae—those brilliant curtains of red, blue and green, with flickering flames. It is seen in the northern and southern hemispheres, generally after a violent sun flare and when the electrons in the outer radiation zone become depleted.

Radiation zones are dangerous for astronauts and electronic equipment. Earth-orbiting space stations will have to keep below 400 kilometres to avoid danger. Satellites going farther should pass through the radiation zones as quickly as possible.

The Atmosphere

Space flights have shown what a beautiful planet our earth is—a blue jewel floating in the black void. Yet, the atmosphere—the sea of air which protects life on the earth—is being increasingly polluted. More than 3,000 foreign chemicals have been identified in the atmosphere. Smoke chimneys and exhaust pipes are adding carbon monoxide, sulphur dioxide and various oxides of nitrogen. We are burning petrol and other fossil fuels at a rate which may soon increase the carbon dioxide in the atmosphere more than what the oceans could assimilate. Carbon dioxide lets in solar radiation but resists long wave heat radiation from the earth to space, thereby creating a heat trap. This may alter the weather itself. As regards oxygen, marine life in the oceans play an important role in replenishing a considerable amount of it. But the oceans are being polluted by oil and other substances, endangering marine life. As technology advances, there is greater risk to Nature's defences found in the atmosphere. The upper atmosphere, for example, may be polluted by the exhaust of supersonic airliners. It may not then be possible for it to stop the lethal radiation from the sun. There is, therefore, growing concern over the preservation of the atmosphere. Satellites which are revealing new features of this great gift of Nature also hold the promise of pinpointing the areas of pollution.

Let us see what the gaseous envelope of air is, as given by Nature and how its different features help man. The nature of the atmosphere



An Outline of the Atmosphere surrounding the Earth

varies not only with altitude, but with geographical, geomagnetic and solar changes. Up to 90 kilometres, the atmosphere is relatively uniform in its content. Hence it is known as the homosphere. The important gases in this region are found in the same proportion, viz., nitrogen 78 per cent, oxygen 21 per cent and argon 1 per cent.

Above 120 kilometres, the gases form themselves into separate layers, depending upon their mass and the gravity of the earth. This region is called the heterosphere.

The area nearest to the earth, known as the troposphere, is the region of the weather. It has clouds, dust and rain. The temperature falls as one goes up. The troposphere extends to 16 kilometres above the equator. The temperature at that altitude falls to —80° C.

In sharp contrast to the troposphere is the region above it, called the stratosphere. This area is calm, with no storm or cloud. The region extends up to 50 kilometres. The temperature starts rising and reaches the freezing point at 50 kilometres. The rise in temperature is due to the absorption of the ultra-violet radiation by the ozone in this region. This also takes in the heat released by the earth. Nothing should be done to upset the ozone layer, which protects life on earth. Above the stratosphere, the temperature falls again. This region is called the mesophere. It ranges from about 50 to 85 kilometres. This is the coldest region in the atmosphere, as the temperature reaches —100° C or even less at times. When meteors fall on this region, they leave a brilliant trail. Above the mesosphere, the temperature goes up again, though at a slower rate. The gas molecules in this region heat up to 500° C and more. The temperature varies, depending on the amount of solar energy received.

The Ionosphere

A useful part of the atmosphere, called the ionosphere, lies in the region between about 60 kilometres and 1,000 kilometres above the earth. This is the 'radio mirror', which bounces back the radio waves beamed from the earth. This is also a complex region where Nature performs several experiments in physics. In this region, solar radiation, particularly ultra-violet rays, creates positively charged ions from the

oxygen and nitrogen molecules present there. The far ultra-violet rays and X-rays are primarily responsible for the different layers of ionosphere. The density of the ions and electrons varies in the different layers.

The layer, which has the least density is also the lowest and is called the 'D' region of the ionosphere. It starts from about 60 kilometres. At night, the D-region is absent. The next region is E, which lies at about a 100-kilometre altitude. The density of electrons is more than in the lower layer, though at night it becomes less. Still above are the F1 and F2 layers, ranging from 150 kilometres to 400 kilometres. The density increases ten-fold and the layers stay during the night also. The higher the electron density, the higher is the reflected radio frequency. Using this principle, a world-wide map of the ionosphere can be made, so that its density profile can be used profitably for radio communications.

Satellites can look at the ionosphere from above. A Canadian satellite, Alouette-1, has in fact attempted such a study. Moreover, it is difficult to send radio beams from the oceans and remote areas to ascertain the nature of the ionosphere over those regions. The latest attempt in the study of the ionosphere is to make a map of it frequently. (Usually made every 15 minutes. Called 'ionograms', these pictures of the depth of the ionosphere, over different localities, will be a new tool for choosing the best frequencies for long distance communications.

Sounding Rockets

Sounding rockets can also analyse the ionosphere Above the magnetic equator (which is a little north of the geographical equator), the ionosphere has several special features. One of them is known as the electro-jet, a narrow stream of high electric current, in the region of 90-130 kilometres. Its impact on weather is an interesting study. The composition of the different layers of the ionosphere is analysed by radio techniques, magnetometers and ion spectrometers aboard sounding rockets.

Indeed, sounding rockets are ideal to ascertain the features of the

atmosphere above the level of balloons but below the level of satellites. In the region between 40 and 200 kilometres from the earth, rockets can make vertical measurements.

There are over a hundred different types of sounding rockets. One can release sodium vapour in the region between 80 and 180 kilometres from a rocket. By photographing the trail, atmospheric winds and temperature could be measured. Another experiment is by exploding grenades. Their speed and sound through the atmospheric pressure, controlled by gravity and solar heating, is measured by gauges in the rockets. The composition of molecular oxygen and nitrogen at lower levels and atomic oxygen at higher levels is studied.

The solar ultra-violet X-rays and the ozone layer are scanned by photometers and narrow-band detectors. Infra-red experiments are done by spectrometers that measure the absorption of solar energy at various altitudes.

Rocketborne instruments study the particle phenomena. They can study the phenomenon called the night air glow—that gives 30 per cent of the light on a moonless night. It will reveal the chemistry of the upper atmosphere.

The cosmic rays and meteors striking the atmosphere, the aurorae and X-rays from outer space are the other areas of investigation by sounding rockets.

The region between 120 and 200 kilometres of the atmosphere above the earth has so far been studied only by sounding rockets. This is because the air drag will cause a satellite in the region fall quickly. This difficulty can be overcome if a satellite automatically changes its orbit to counter the drag. The new technique is going to be tried soon, by a satellite.

The air drag in this region has acquired great importance, as on that would depend the design of the space shuttle, which would be used again and again, unlike the present once-only rockets. If a shuttle could find a place and time with minimum drag to pass through this region easily, it would greatly facilitate future space transport.

Another field of study that has become important is the interaction between the radiation zones and the upper atmosphere. An Explorer

satellite studied the polar regions, where energetic particles penetrate the atmoshpere more deeply than in the regions near the equator. It has been found that the atmosphere is heated by the ultra-violet radiation and energetic particles, such as protons and electrons, trapped in the earth's magnetic field. Following magnetic disturbances, air density increases. It also fluctuates with the eleven-year solar cycle. Indeed, the density of the upper atmosphere, where the gases stay separated by their weight, varies from day to day.

The earth's atmosphere extends to 48,000 kilometres. Even there, a few hydrogen atoms could be found.

Above the Atmosphere

WHILE the atmosphere protects life on the earth, it absorbs most of the electro-magnetic waves, except visible light and radio waves. Visible light is only a small window to see the universe. Even that is distorted by the scattering of light in the atmosphere. Besides visible light, energy in space comes in other forms of electro-magnetic waves. The range of such waves is called the electro-magnetic spectrum. On the one end of the spectrum are radio waves followed by infra-red, visible light waves, ultra-violet, X-rays and gamma rays.

In 1931, Karl Jansky discovered that the earth was being bathed in radio noise. That was the birth of radio astronomy. In the next four decades, radio emissions were found to be coming from the sun, other stars and galaxies, and even from cold planetary bodies.

X-rays and Black Holes

Since 1962, several sources in our Milky Way Galaxy were found to emit X-rays. X-ray stars and X-ray galaxies have been detected. Their average X-ray output was about 1,000 times greater than the total energy output of our sun! Some X-rays have been found coming from the Crab Nebula (a star remnant believed to have exploded nine centuries ago) at the rate of 30 pulses a second.

Today satellites explore X-ray sources. Explorer-42 was the first

X-ray astronomy satellite. A big advantage of this is that an X-ray source can be observed regularly, while the satellite continues its orbit. Since X-rays penetrate far, the new device may well reveal the centre of our galaxy. The satellite has already found more than 13 new X-ray sources. They include several far off galaxies.

One of the mysteries detected by the satellite is an X-ray star which pulsates in the Constellation Cygnus. One view is that this may be the theoretical black hole. It is so called because it cannot be seen, as even the light waves from it are held back by the unimaginable gravitational force of the star. The theory also says that surrounding the black hole, there would be X-rays in abundance. When matter in a star collapses, it may reach that stage. Its nuclear density may be several hundred million tons per cubic centimeter.

Until Explorer-42 was launched, only the galaxy M87 was known to emit X-rays. Now it is believed that X-rays come from a much wider area in this region.

These interesting new findings are part of the story of the birth and death of stars. When a star explodes, the nuclear reactions release vast energy, giving rise to cosmic rays and magnetic fields to speed up these rays. One of the recent discoveries is the vast explosions which change huge amounts of matter into energy, which comes to us in the form of radio waves. They are called quasars (quasi stellar objects) or radio galaxies. It is now believed that Quasar 3C 273 emits X-rays. It is about a thousand million light years away. While the radio window has revealed even galaxies emitting radio waves, the X-ray window has opened recently. As if to complete the picture, a galaxy in gamma rays has been found by Soviet astronomers with the help of Cosmos satellites.

Other satellites have observed stars in the ultra-violet range of the spectrum. They include giant stars, 100 times as large as the sun and stars in various stages of evolution. Several stars are reported to be brighter in the ultra-violet region than in the visible region.

Ultra-high energy radiation does not merely reveal new worlds but provides the key to understanding the magnetic fields, density of matter in the particles in outer space and other cosmic puzzles. They may throw

some light on the creation of matter and the physical forces in the universe.

The Sun

The sun, which sustains life on the earth, is the only star which man can observe directly to study its features and its X-rays, gamma and radio emissions. The energy of the sun is enormous. In just one second, it is estimated to emit more energy than all the people of the world had used in the entire history. Only satellites going above the atmosphere can study the solar features.

Revolving at 150 million kilometres from the earth, the sun has a diameter a hundred times that of the earth. It has a mass 332,000 times greater than that of our planet. It makes a full rotation on its axis about every 27 days. However its behaviour is unpredictable. Occasionally, giant flares rise to millions of kilometres above its surface. Dark spots also appear on its surface at times. Though the sun looks without any surface features, it does appear to have a fine grained structure.

Scientists recently photographed for the first time the life and death of a solar flare. The Orbital Solar Observatory-7, took the photograph every eleven minutes. The flare disintegrated into huge plasma clouds, each capable of gulping forty earths!

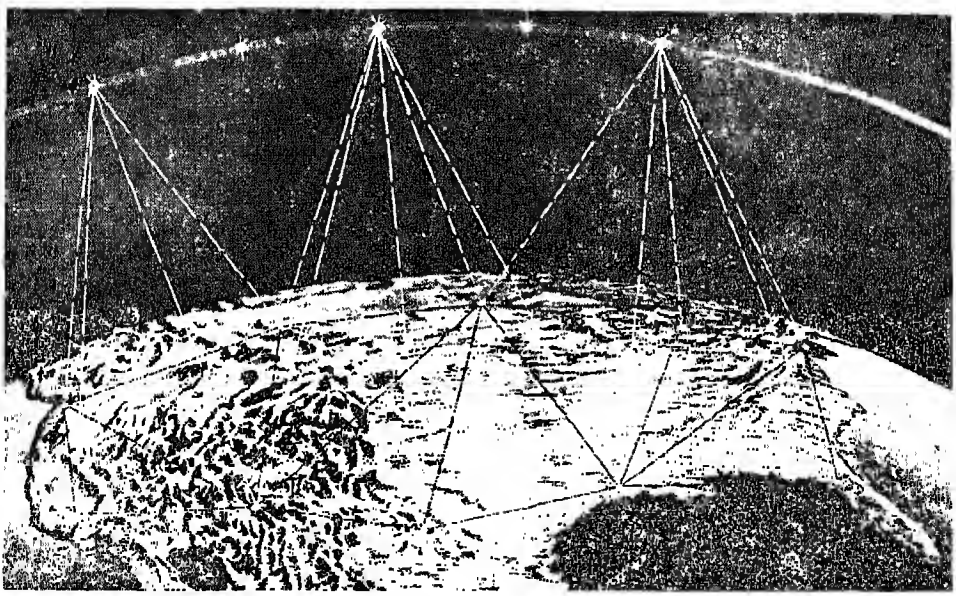
The first satellite in the OSO series observed more than 140 solar flares and sub-flares. It also confirmed the theory that solar wind reaches the earth's atmosphere.

The sun's activity is marked by a eleven-year cycle during which solar eruptions reach from a maximum to a minimum and then again to a maximum. The Americans have launched another series called Pioneer, for studying inter-planetary space continuously from separate points during a full solar cycle. Pioneer-V, for example, confirmed inter-planetary magnetic field, while others in the series indicated that the solar wind is made up of very few atomic particles of hydrogen, helium and other elements. But their energies are smaller compared to those of cosmic rays, also emitted by the sun. Pioneers have indicated that cosmic rays spiral around the solar magnetic lines.

Several cosmic satellites, rockets and Prognoz spacecraft of the Soviet Union have also studied the solar features and are trying to find a basis for predicting solar flares, which affect not only space travel but also the weather and radio communications.

The Earth's Shape and Gravity

Satellites have improved our ideas of the earth's surface. The orbits of satellites often deviate from the calculated path. This is because the size and shape of the earth, its gravitational field and its hidden struc-



Triangles for accuracy in determining the location of places and the exact distances between them. Simultaneous observation of a flashing light on a satellite from a few ground stations is used to measure distances across a continent.

ture, affect its orbit. As a result of satellite observations, the shape of the earth is no longer imagined as a flattened tomato. It is more like a pear, slightly broader at the bottom than at the top. Satellites have also shown that the equator is elliptical rather than circular. They have

also revealed irregularities in the surface area including some under the oceans. They are due to uneven distribution of the earth's mass. The surface gravity of the earth indicates its form. Thus geodesy has become a sophisticated science dealing with the earth's mass, shape and size, its gravity variations and the distances between points on the earth.

Geodesists can calculate distances between points in two continents, to within metres. A knowledge of the irregular gravitational fields enables us to launch, guide or track a satellite precisely. The technique is useful for navigation also.

Accurate Mapping

Accurate mapping of the earth is done with the help of geodetic satellites. This is done in several ways. One is to draw triangles to calculate the coordinates of unknown points by a method called triangulatoin. It is based on the fact that if any two ground stations and the satellite's position are known, the coordinates of the unknown point can be located. This is done by photographing the satellite. Another method is by deducting from the radio or light waves from a satellite their travel time and thus their distance. Although the satellite transmits at the same frequency, it is observed as changing on the earth, as the satellite approaches and leaves the observation point. Recall how the whistle of a speeding engine goes up in pitch and then dies down after it crossed you. This is called the doppler shift. From the observations of the doppler shift, scientists can either calculate the orbit of a satellite or the location of an unknown station.

Over 500 satellites in the Soviet Cosmos series and over 40 American spacecraft in the Explorer series have been launched to study the various aspects of near and outer space.

Space Science in India

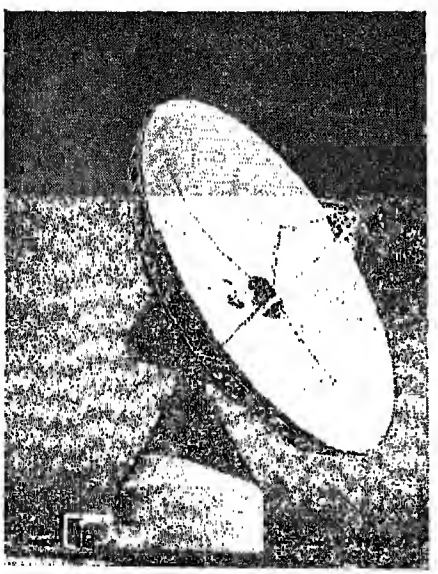
Studies relating to space science were made in India even in the last century. The earth's magnetism was studied in different parts of the country. Shortly after the beginning of this century, a magnetic map of India was made. In 1868, a major solar eclipse which crossed India was studied scientifically. During another eclipse in 1871, several features of the outer region of the sun's Corona, were observed. From 1900, the Solar Physics Observatory in Kodaikanal in Tamil Nadu started taking pictures of the sun. One of the oldest libraries of solar pictures is there. As Kodaikanal is rather a cloudy hill station, another place, Kavalur, near Jolarpet also in Tamil Nadu, has been selected. When the new telescope is ready, the field of observations, particularly in the southern milky way, would be enlarged.

Plastic Balloons

Pioneering work has been done in our country in the field of cosmic rays also. In the equatorial regions, where the earth's magnetic field is maximum, only the high energy radiation is allowed to enter. Cosmic ray studies were started in the late 1940s. Since 1959, the Tata Institute of Fundamental Research has done cosmic ray investigations near the geo-magnetic equator. Special plastic balloons have been fabricated for this purpose. A typical balloon has a volume of 85,000 cubic metres.

and recovered with the aid of parachutes. The studies probe the state of cosmic space through which the rays travel and throw light on magnetic fields in space and other related data. Recently, our scientists have discovered X-ray sources in the sky. The neutrons emitted from the sun have also been studied.

The late Dr. H. J. Bhabha established the nucleus of what eventually became the Tata Institute of Fundamental Research in Bombay. Another important institution is the Physical Research Laboratory set up in Ahmedabad in 1948. The Laboratory is engaged in the study of cosmic rays, astrophysics, radio and X-ray astronomy and cosmic-terrestrial relationship, geomagnetism and the technique for studying space physics. Scientists of the laboratory actively collaborate in the work done in other centres of space study. They also study the real time data from some scientific satellites while orbiting over India. A ground station at Arvi, near Poona, caters to satellite communications.



The antenna at Arvi

A major facility in the field of radio astronomy was set up in Ootacamund in 1970. The radio telescope there studies distant radio galaxies. The 530-metre-long telescope consists of a parabolic cross-section of stainless wires to catch the radio signals coming in from outer space. The signals are reflected and brought to a focus before being carried to a receiver for record. Over 200 sources have been observed. The telescope is steerable and therefore enables the scientists to follow radio sources in the east-west direction for nine and a half hours a day.

The study of the upper atmosphere has been conducted with very sensitive equipment at the High Altitude Research Laboratory at Gulmarg (Kashmir). Set up in 1963, the Laboratory records very small variations in the atmospheric pressure waves. They are closely connected with weather conditions. The Laboratory also studies the radio waves emitted by some stars and even galaxies, besides solar radiation and the phenomenon of night airglow.

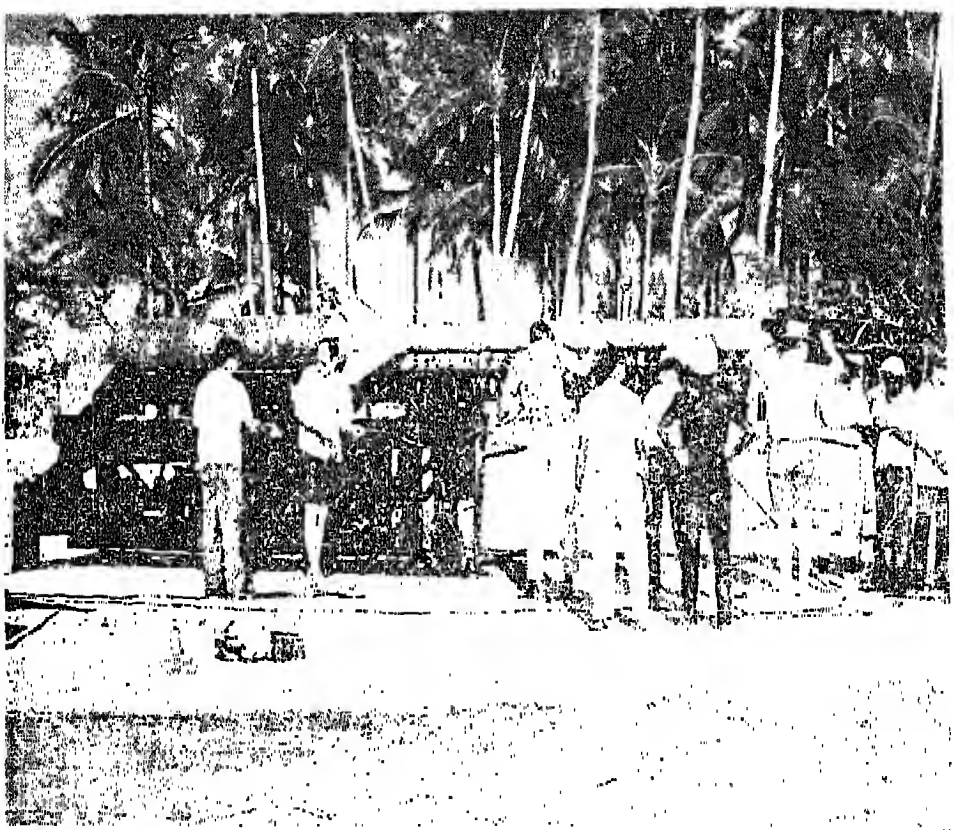
Thumba

The exclusive features of the atmosphere above the magnetic equator are studied with the help of rockets sent from Thumba, near Trivandrum. It is the world's first ground-based sounding rocket facility. It became operational in 1963.

The Thumba Equatorial Rocket Launching Station has to its credit over 400 launchings; one-third of them carried experiments in the upper atmosphere. About 2,700 persons are engaged in indigenous design and development of rockets. Over 75 Soviet M-100 rockets have been launched for meteorological study. More such rockets will be launched to gather information on the way the south-west monsoon sets in over the Indian peninsula. Other launchings studied the electron density of the ionosphere, the phenomenon called equatorial electro-jet, changes during magnetic storms, winds in upper atmosphere and electric fields in the ionosphere. A Space Science and Technology Centre in Thumba set up in 1965, also conducts studies but with emphasis on technology.

Sriharikota

As India developed her own satellite programme, a launching site on the east coast became essential. This is to take advantage of the earth's spin, while launching rockets and at the same time avoid populated areas coming under the rocket's trajectory. An ideal site was located in Andhra Pradesh, called Sriharikota, 96 kilometres from Madras. The new rocket range was commissioned in 1971, when its first phase was completed. Indian-made rockets are now being launched from there while facilities for handling the launch and control of India's



A Sounding Rocket being assembled on the Launcher at Thumba

own satellite are being provided. In 1974, a scientific satellite, wholly designed and made in India, will be launched by a Soviet rocket carrier from Soviet territory.

4

JOURNEYS TO THE MOON

When an elderly and distinguished scientist tells you that something is impossible, he is almost certainly wrong .

ARTHUR CLARKE

Early Attempts

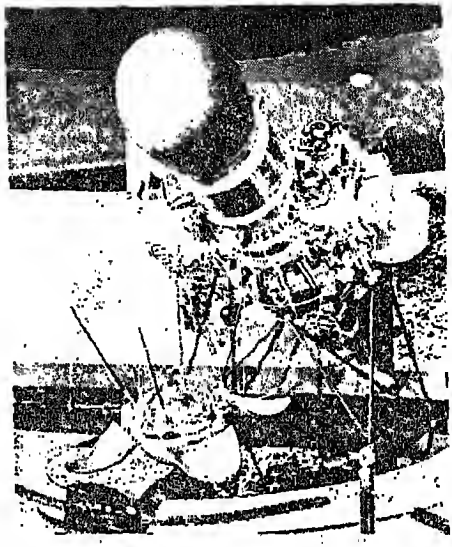
THE moon has inspired man to go into poetic raptures. The silvery cool radiance has punctuated many aspects of his life besides being of use in reckoning time. King Solomon gave the Queen of Sheba a flying machine to go to the moon. But Don Quixote imagined a fellow being carried away towards the moon by some devils. Juliet pleaded with Romeo not to swear by the "Inconstant moon". But the moon has been a constant witness to life on earth.

The age of the rockets turned poetry into adventure. From being sheer adventure, the exploration of the moon has now become a scientific goal. The new techniques and the new knowledge have set new goals in space exploration. Let us first see how it all started.

Several unmanned satellites were sent to the moon to unravel its mystery. The Russians were the first to send a spacecraft moonward. It was known as Luna-1. But it bypassed the moon. That was in 1959. The same year, Luna-2 crashed on the moon and the next spacecraft phtographed its hidden side.

The American effort succeeded in 1962, when their spacecraft, Ranger-4, crashlanded on the moon. In February 1966, the Soviet Luna-9 made the first-ever soft-landing on the moon and sent back TV pictures. A few months later, the Americans repeated the feat with Surveyor-1. The next Russian effort saw another first. Luna-10 became a satellite of the moon. The Americans soon caught up. Their spacecraft,

Orbiter-1, also circled the moon. The Russians again scored a first. Luna-13 tested the soil with a long arm, driven by an explosive jet. Not to be left out, the Americans sent Surveyor-3, which sampled the soil. Surveyor-5 and -6 did a little jumping by moving to a new site, over two metres away. The last of the series, Surveyor-7, softlanded on the high lands near the Crater Tycho, which emits bright rays at full moon. It also did soil-testing and returned over 20,000 pictures.



Luna-9 (model) which first soft-landed on the moon

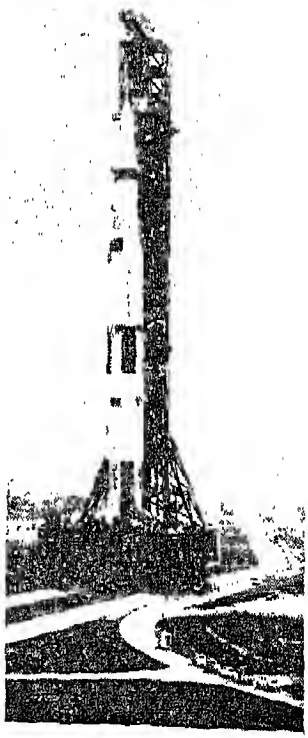
The Soviet Union, meanwhile, orbited Luna-14 in 1968 to study the space near the lunar surface and gravity. That year was noted for another new achievement. A new unmanned spacecraft called Zond-5, heavier than the Luna series, circled the moon and returned to earth, splashing down in the Indian Ocean. It contained several biological specimens. Zond-6 performed a similar journey but came down on land. Before the next Zond mission, Luna-15 was sent in July 1969. It began its journey three days before the Apollo-11 astronauts started their mission. The day before the Americans landed on the moon, Luna-15 went into a new orbit which sent it within 16 kilometres of the lunar surface. This increased the speculation that the robot might beat the men in scooping up the lunar dust. But the Russians announced that their spacecraft had ended its work. It had crashed at a point 800 kilometres away from the astronauts. Zond-7 followed this mission and brought home colour pictures of the moon. The Russians disclosed that there were improved on-board systems. Again in October 1969, Zond-8 zipped around the moon, bringing back a load of pictures of the lunar

surface. It splashed down in the Indian Ocean. Zond-8 also served as the target for a new Soviet telescope, which picked it up at a distance of over 300,000 kilometres from the earth and tracked it for nearly three hours. It was claimed that this method would help locate a spacecraft precisely.

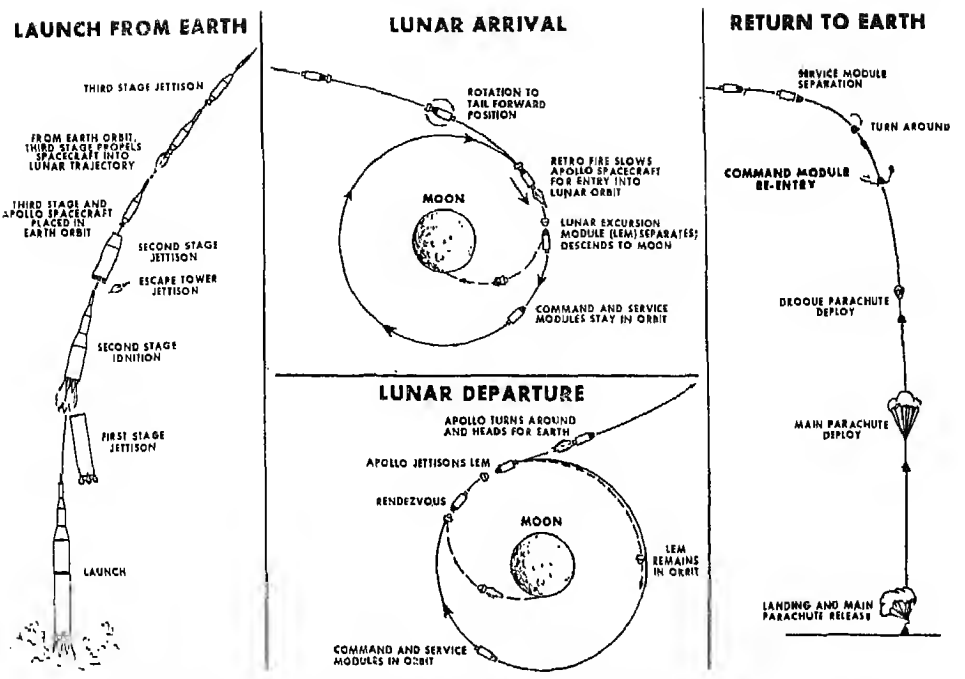
Men and Science in Action

TWENTY days after the first American astronaut completed just a sub-orbital flight in 1961, the late President Kennedy announced his decision to land men on the moon. The complex technology needed for that feat was not there at that time. Step by step, experiments were made and the designs of the present-day rockets and spaceships perfected.

Five years later, the command ship of Apollo was successfully tested. The heat shield to protect it from the extreme temperature during re-entry worked well. It was an unmanned vehicle, boosted by a rocket called Saturn 1-B. Two more unmanned tests were made in 1966. Next year, the giant rocket Saturn-5 and Apollo-4 were flight-tested. The first and second stage could be re-started, while in orbit. In January 1968, Apollo-5 was tested, with the first Lunar Module inside. It went into an earth orbit and proved that man could stand it. Another unmanned mission, Apollo-6, found no serious problem. It



The world's biggest rocket, Saturn-5, on way to the launch pad



Sequence of major events in Apollo lunar landing mission

was then decided to test Apollo with men on board. Astronauts Walter Schirra, Donn Eisele and Cunningham successfully completed their eleven-day mission aboard Apollo-7. The spacecraft systems were made extra fire-proof. Their aim was to test-fire the all-important service propulsion system engine. Also for the first time, live television was provided from a manned spacecraft.

Ring Round the Moon

Then came the memorable ring round the moon. It was the Christmas of 1968. For the first time, three astronauts Borman, Lovell and Anders in Apollo-8 freed themselves from the earth's gravitational field and came under the influence of a heavenly object's gravity. They saw

the grandeur of the moon, including its hidden side.

Launched by a Saturn-5 rocket, the astronauts first circled the earth. When their systems were working well, they refired the third stage of the rocket and broke away from the pull of the earth towards the moon. The object was not to hit the moon but to miss it by a certain distance and then fall into an orbit. As they 'sailed' towards the moon, the earth's gravity reduced their speed, until they arrived in the vicinity of the moon. From a speed of 39,260 kmh. when they left the earth's pull, their spacecraft slowed down to about 3,400 kmh. and as the moon pulled it, picked up speed again to a peak of 9,000 kmh., just before entering into orbit. A lunar orbit can be achieved only if the speed is reduced to 5,800 kmh. This was done by firing the rocket to brake the speed, instead of increasing it, so that the moon may capture them in orbit. They had to fire the engine while they were behind the moon, out of touch with the earth. As they passed behind the moon, there was complete silence. Thirty-five anxious minutes ticked by. And to the relief of the ground control, Apollo-8 reappeared from behind the moon in lunar orbit. First they inserted themselves into an elliptical orbit around the moon and after two such trips, fired their rocket again to circularise the orbit at a 112 kilometre altitude. They took two hours to complete one orbit and after ten orbits, they fired their main engine again, this time to increase their speed and break away from the grip of the moon and return home.

While in orbit around the moon, the astronauts described the gallery of the lunar scenes revolving below them. They read the opening verses from the *Book of Genesis* on the creation of earth.

The six-day 800,000 kilometre-voyage ended with a perfect splash-down. The spacecraft turned upside down in water but was soon set right. After escaping the hazards of the endless void, the astronauts nearly got caught with a shark. But they scrambled into their rescue nets and helicopters hoisted them to safety.

A Funny Spider

The Lunar Module, which would land man on the moon and lift

them back, was however not tested in the Apollo-8 mission. That was done by the Apollo-9 astronauts but in space near the earth. It was a ten-day earth orbital mission. The Lunar Module, code named Spider, proved itself in space by reuniting with the command ship. The 'Spider' will fly only in space, as it has no heat shield to be brought back to the earth. Astronaut Schweickart emerged from the 'Spider' and got into the 'golden-slippers', the gold-painted restraints on the ship. For 46 minutes, he was a human satellite, zooming half way around the earth. He tested the self-contained space suit to be worn by an astronaut on the moon. While orbiting 216 kilometres above the earth and out of sight of the mother ship, the Spider simulated a descent to the moon and an ascent from it.

After its successful performance near the earth, another Lunar Module was taken to the vicinity of the moon in the next mission, Apollo-10.

Final Dress Rehearsal

The final dress rehearsal for lunar landing was made by Astronauts Thomas P. Stafford, Eugene Cernan and John W. Young, flying Apollo-10. The command ship was named Charlie Brown and the Lunar Module, Snoopy, after characters in a popular comic strip. Snoopy descended to within 14 kilometres of the moon for a close-up study of the landing site for the next mission in the Sea of Tranquility. The astronauts tested the landing radar and photographed the sites. There was colour television this time and besides the moon, the earth was also shown from various points. The moon appeared in different colours under different lighting conditions. The surface was brownish tint, but the boulders were black and grey.

A Giant Leap for Mankind

On July 16, 1969, after eight years of preparation, man began his journey to land on the moon. Over a million people watched the lift-off at Cape Kennedy. The launch was perfect, as the rocket with Apollo-11

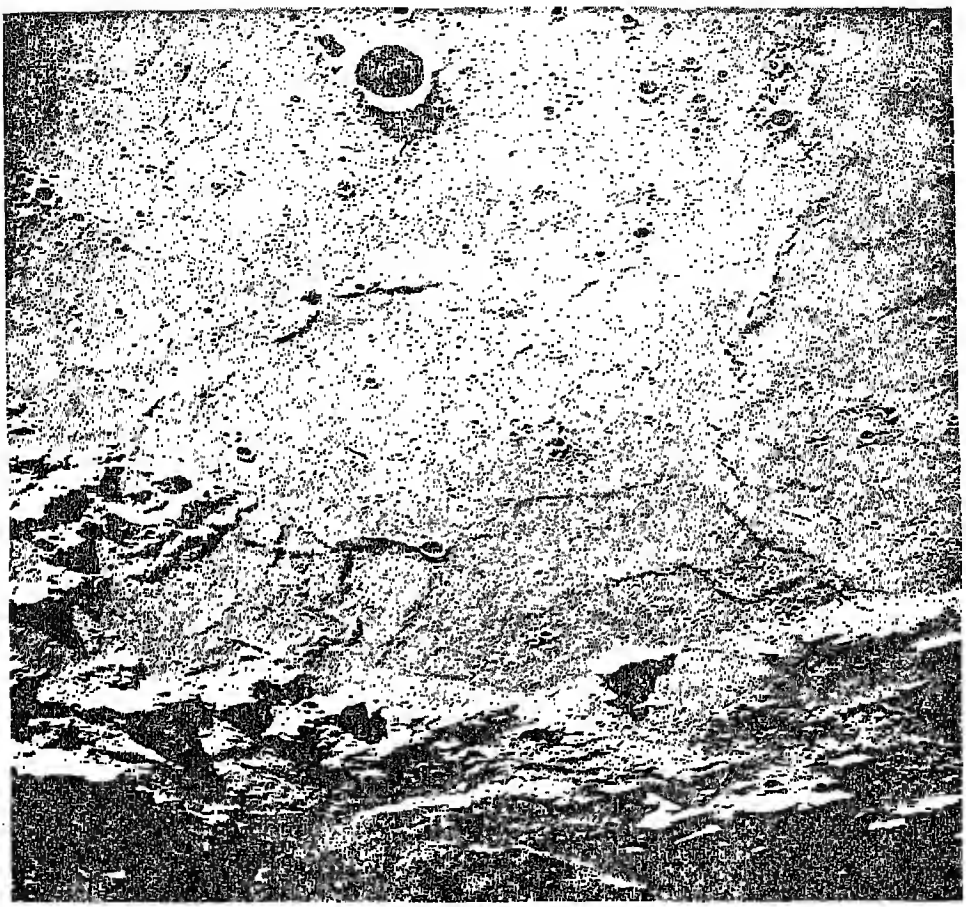
Neil Armstrong —the First Man on the Moon

climbed to a deafening roar. It was truly a voyage of discovery as the effect of lunar gravity on a spacecraft was still a mystery. Neil A Armstrong, 38, was its commander, while Edwin Aldrin, 39, was the Lunar Module pilot and Michael Collins, 38, was the Command Module pilot.

Unlike the earlier Apollo crew, they spent their first night in space in deep sleep. Everything was so perfect that a planned mid-course correction was cancelled. The Command-Service Module was called 'Columbia' and the Lunar Module 'Eagle'.

Tranquillity Base

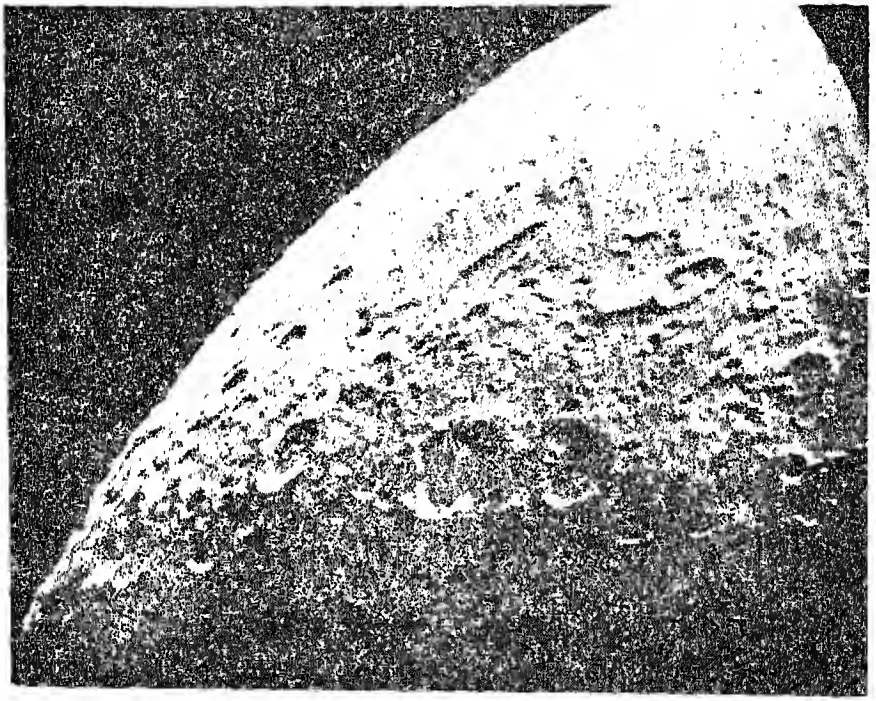
The fragile spacecraft made a frightening but safe touch-down at 40 seconds past 1.47 a.m. (IST) on Monday, July 21, 1969. In a voice hardly raised from his normal manner, Armstrong reported, "Contact light on. Engine off. The Eagle has landed". Centuries of man's dreams materialised. Aldrin reported "very smooth touchdown". Armstrong gave a quick description of the scene. Among the first details to be confirmed was the angle of tilt of the Lunar Module. It was well within the capacity to take off from the moon. Within seconds, ground control was addressing Eagle at "Tranquillity base". Armstrong disclosed how in the final moments before landing, the overworked computers were taking them to an area of craters and he had to take over control manually to find a reasonably smooth area. At 8.26 a.m. (IST) on the same day (July 21), Armstrong stepped on the moon. As he set foot on the lunar surface, Armstrong observed, THAT'S ONE SMALL STEP FOR



The Desolate Grandeur of the Lunar Landscape. One of the landing areas selected for Armstrong. Topographic features shine brilliantly because of the low angle of the sun.

A MAN, ONE GIANT LEAP FOR MANKIND. He later said that he felt like swin ming in an ocean, with two to three metre waves. At 8.44 a.m., Aldri stepped on the lunar surface. They collected rock samples and set u scientific experiments.

The men from earth put a plaque reading: HERE MEN FROM TH



A View of the Moon as seen from the Earth

PLANET EARTH FIRST SET FOOT UPON THE MOON. JULY 1969 A.D. WE CAME IN PEACE FOR ALL MANKIND. They also left a tiny silicon disc containing miniaturized messages from world leaders and the medals of two Soviet space heroes, Gagarin and Komarov.

Aldrin returned to "Eagle", ending his moon walk, spending 103 minutes outside the spacecraft. Armstrong followed him and was back to the Lunar Module after 213 minutes outside. Nearly thirteen hours later came another anxious moment, when "Eagle" lifted off from lunar surface. The world's first lift-off from the moon without elaborate outside help, came at 11.24 p.m. on July 21 after Armstrong and Aldrin

stayed on the lunar surface for 21 hours and 37 minutes. They left as they came, riding a column of flame. In the next four hours, Eagle and Columbia circled the moon, coming closer and closer to each other. It was like a ballet in the void, ending with the crucial docking at 3.05 a.m. on Tuesday, July 22. They then jettisoned their moon-lander's upper stage in which they took off from the moon. About seven hours later, the astronauts fired their rocket engine to return home. On July 24, Apollo-11 splashed down safely in the Pacific Ocean.

The footprint-by-footprint schedule of man's first day on the moon went through without any mistake. As millions watched them on live television, the astronauts proved that one-sixth gravity was not a menace but only a limitation. They preferred the one-sixth gravity to the earth's gravity or the zero-gravity in space. Armstrong felt like a young boy in a candy store with too many interesting things to do. They would have loved to have a few moments just to enjoy the sensation of being there. They were able to pick up a variety of rocks, despite the heavy gloves.

The astronauts installed three experiments. One is called a laser beam reflector. Made up of precise optical reflectors, it will bounce back an intense ray of light beamed from the earth. By timing the trip of the light to and from the moon, the distance between the earth and the moon can be precisely measured within 15 centimetres of the exact figure. It can one day help man to predict earthquakes. Another instrument left behind was a seismometer, to measure the impact of any movement inside the moon's inner structure. The third experiment was a solar wind collector. It would collect the particles from the solar 'wind'. The sheet which collected it was brought back. It was a Swiss experiment.

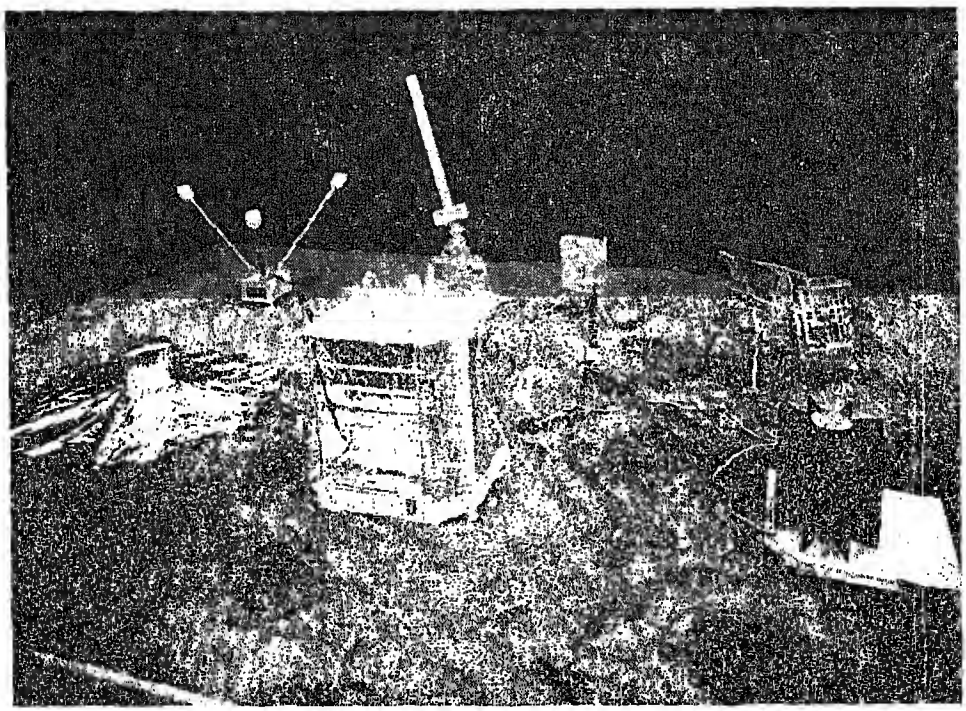
There was no red carpet welcome to the moon heroes. It was feared that some unknown germs from the moon may spread disaster. Before the astronauts came out of their command ship, they were given special garments to prevent the spread of germs, if any. As they floated on the waves, a special chemical was sprayed on them. Then they spent eighteen days inside a quarantine laboratory, where the moon samples were examined. But the fears proved baseless. The astronauts were

hale and hearty. So were the organisms exposed to moon dirt.

A Lunar Laboratory

The primary objective of Apollo-11 was to land the astronauts on the moon and bring them back safely. Apollo-12, launched on November 14, 1969, enabled the astronauts to explore the moon scientifically.

A notable feature of Apollo-12 was the bull's eye landing by the Lunar Module, Intrepid, in the Ocean of Storms on the western side of the moon. 'Intrepid' touched down just 183 metres from Surveyor-3, the unmanned spacecraft sent in 1967. In the Apollo-11 mission, dumping of waste water outside the spacecraft altered the speed of the space-



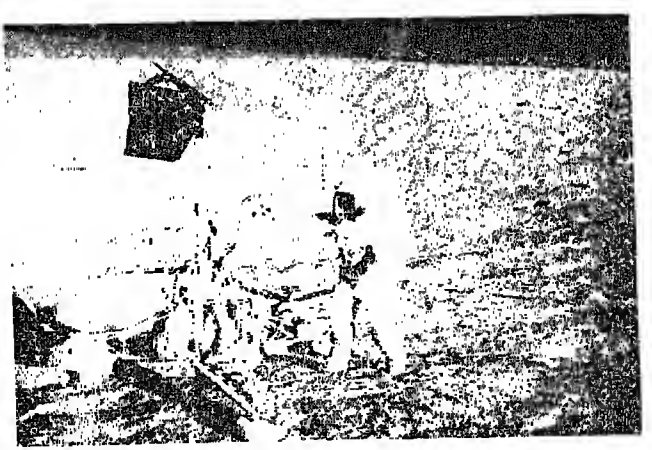
Experiments on the Moon (from left to right clockwise) : Passive Seismic Array, Magnetometer, Ion Detector, Case of Tools, Nuclear Power Source and the Central Station

craft by a few metres per second and such changes piled up into errors. This was avoided in Apollo-12.

Astronauts Charles Conard, Alan Bean and Richard Gordon of Apollo-12 proved that man could work on the moon. Conrad and Bean set up the first automatic scientific laboratory on the moon. Conrad emphasised the role of the human hand in installing Plutonium-238, a dangerous but useful nuclear power source, into the experiment package on the moon. The lunar laboratory consisted of a nuclear-fueled generator, a radio station and instruments to collect and transmit data. A seismometer was also installed. This would tell man about the lunar interior through the pattern of shock waves registering on it by the impact of meteorites or any object on the moon. Other instruments left behind measured, for the first time, the moon's magnetic field, its thin lunar atmosphere and ionosphere. Another gadget detected gases leaking from the moon into space.

Clipping an Old Bird

During their second walk on the moon, the two astronauts walked



An Apollo-12 Astronaut on the Moon inspecting the television camera prior to detaching it from Surveyor-3, the unmanned craft which soft-landed 31 months earlier

over to the Surveyor, which was inside the rim of a shallow crater. They walked down and retrieved parts of the unmanned craft to study how much it had been 'spoiled'.

Conrad and Bean whistled and sang as they worked! They became thirsty but not tired. Conrad spent about 8 hours and 44 minutes on the moon outside the safety of the Lunar Module, in two 'walks'. He fell and stood up again without difficulty. He compared his walk to a giraffe in slow motion. The crater slope provided no difficulty. The Surveyor had changed its colour during its stay on the moon. Man could touch the machine he himself sent years ago to a celestial body.

The Moon Suit

Let us have a look at the suit worn by the astronauts on the moon. It is a pressurized suit which keeps them at a comfortable temperature and gives them pure oxygen to breath, as there is no air on the moon and its temperature goes to extremes (+121° C and —157° C). A suit-case sized box, carried on the back, supplies water and oxygen. This has a special oxygen supply to last for half an hour by which time he can return to the Lunar Module. This is in addition to the four hours operating time given normally by the back-pack. An undergarment which is cooled by circulating water is also worn while working outside the spacecraft. There are also facilities to talk by radio to the ground control and to his colleague on the moon. The moon-suit is composed of sixteen different layers of material. There is also an insulated over-coat to protect the astronauts from the meteorites, travelling at over 1,00,000 kilometres an hour. Their visors would protect them against solar ultra-violet and visible light radiation. The suit is no doubt heavy and somewhat restricts the movement of the astronauts on the moon. In later missions, the suit was redesigned to increase the mobility of the astronaut.

A Saga of Endurance

The success of Apollo-12 made people look at the moon journeys as routine. But Apollo-13 gave a jolt. The flight was commanded by

James A. Lovell. Fred W. Haise and John L. Swigert were his colleagues. The flight was apparently perfect in the beginning and the first mid-course correction was cancelled. But after 56 hours of flight, on April 14, 1970, Commander Lovell reported, "Hey, we've had a problem." A bang was heard. Lovell reported that gas was coming out of the spacecraft. This made the spacecraft roll and it took them some time to control the tumbling. The oxygen pressure was dropping. The fuel cells, which supply electricity to the spacecraft and water for the astronauts, were damaged.

'Marco Polo' of the Space Age : James Lovell

The plan to land on the moon was abandoned. The only concern then was to plan the safe return of the astronauts. The crew had to evacuate to the Lunar Module to stay alive. The meagre electric power supplied from the batteries of the commandship was reserved for re-entry. The astronauts talked to the ground control, using the moon-landing craft's radio.

When the accident occurred, the spacecraft was more than half-way to the moon. It could not just turn round. In space, gravity does not permit it. They had to go all the way to the moon and circle it. Only then could they get back.

The best of brains on the ground strained to work a way out. It was clear that the main engine in the Service Module could not be used as the fuel cells there had been damaged. The only other engine was the one in the descent stage of the Lunar Module. It was decided to use this. First, the astronauts should fire it to place themselves on a

trajectory, which would return them to the earth. Once behind the moon, another crucial burn had to be made before they could free themselves from the grip of the moon's gravity. The duration of the burn of this engine was planned on the ground after elaborate calculations. Though the engine fired well, there was some unexpected deflection in the flight path and this needed further correction.

Inside the spaceship, carbon dioxide was building up. Water was becoming a problem. The astronauts were using their limited power supply with great care. Calculations showed that there was enough water. Also, there was a safe margin of oxygen supply. This only showed that, had the accident occurred after the Lunar Madule was jettisoned, it would have proved fatal.

The Lunar Module, meant only for going to the moon and returning to the commandship orbiting above it, worked well till the last. On April 17, the final course-correction was made using that engine again. Then all the three astronauts got into the Lunar Module and jettisoned the damaged service module. As they floated away from it, the astronauts found one whole panel being blown off the service module. It was not discarded earlier for fear that without its weight, the flight path might be affected.

After three hours, they crawled into their commandship and made good-bye to the Lunar Module and jettisoned it. As it had no heat shield to return to earth, they had to depend on the Command Module. From this stage, it was like any other trip, except that it was the fastest re-entry for an Apollo capsule returning from the moon. After the usual radio black-out, Swigert's voice established contact. Watched live on television by an unprecedented number of people, the orange and white parachutes splashed down only a few seconds late, just within six kilometres from the recovery ship in the Pacific.

Thus ended a saga of human endurance, intelligence and courage. The three astronauts stepped out of the pages of science fiction into real life. A delighted Mrs. Lovell ran from room to room in her home! The unsung heroes on the ground had worked out every possible step in advance. The conditions of the spacecraft were re-created and their fellow astronauts endured them to try what could be done, before those

in trouble, were advised.

An elaborate enquiry was ordered into the mishap. The review board, in its 931-page report, said, "the accident was not the result of a chance malfunction in a statistical sense, but rather resulted from an unusual combination of mistakes, coupled with a somewhat deficient and unforgiving design." The cause of the explosion in the Service Module was fire in an oxygen tank, caused by an electrical short circuit. Following the recommendations, it was decided to remove the fans used to stir liquid oxygen, as it was found that they were not necessary up to a point. An additional oxygen tank was added to the Service Module and wirings were covered with fire-resistant stainless steel. Alarm systems were also improved.

A Long Way and a Long Stay

Date: February 5, 1971; Time: 8.24 p.m. IST; Place: Fra Mauro region on the moon; Event: The fifth human imprint on the lunar surface – that of Alan B. Shepard, 47-year old Commander of the Apollo-14 mission. Nine years and nine months before that day, Shepard had become the first American to go into space. "It's been a long way; but we're here" he said meaning not merely the 3,78,000 kilometres separating him from home but also the long battle he had waged to overcome his ear trouble, a dangerous defect for an astronaut.

The landing was 'touch and go', until the last three minutes. To gain more hovering time over the landing area, the Lunar Module separated from the mother-ship from a low height of 17.7 kilometres from the moon's surface, unlike the earlier missions, when the Lunar Module began its separate journey from a distance of 112 kilometres from the surface. Despite this improvement, there was trouble. The computer gave alarms, which meant it would automatically abort the landing and fire the retro-rockets to get away from the surface. Hurried checks were made at ground control, and the computer was asked to ignore its own commands. A few minutes later, it was discovered that the villain of the piece was a malfunctioning switch, which became normal when the astronauts tapped a panel.

The landing was perfect. It was the first on the highlands of the moon; the previous astronauts had settled on relatively smooth plains.

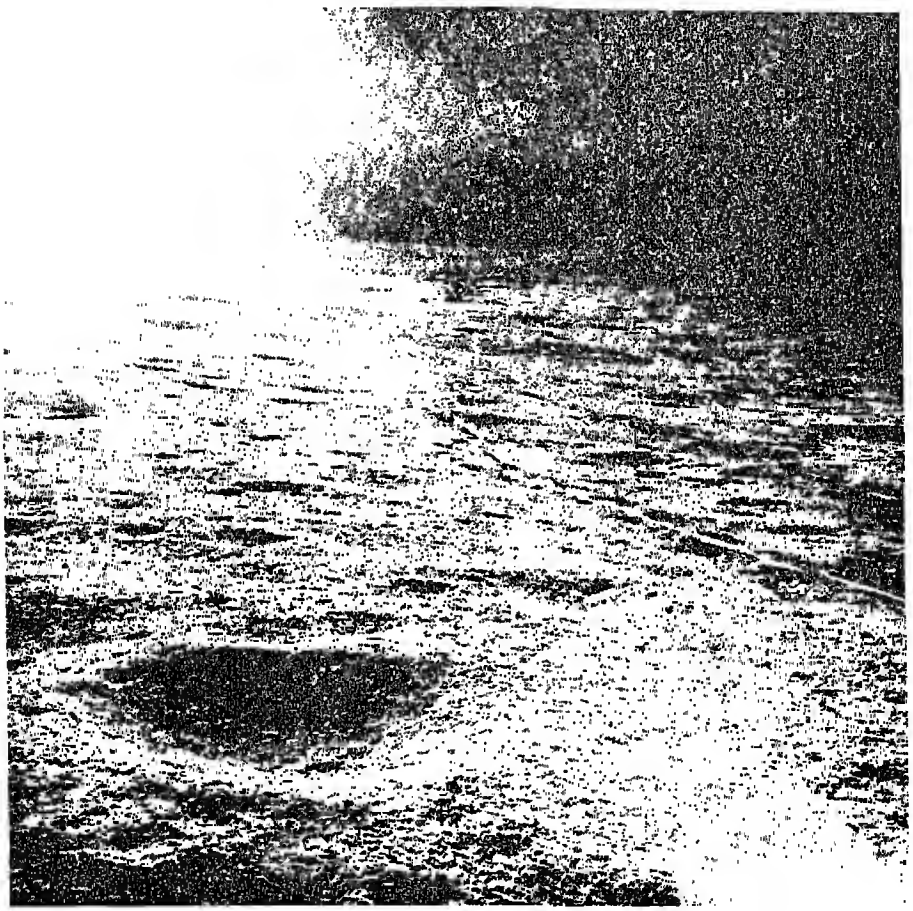
The smooth landing was in sharp contrast to the troubles earlier in the mission. The launching was delayed by forty minutes because of bad weather. Later, there was trouble in docking with the Lunar Module. The astronauts aboard the commandship tried five times but failed. It seemed for a while that the moon-landing mission would be aborted. But the sixth attempt was successful. They showed the docking mechanism on television but nothing wrong was found. Perhaps some ice crystals were blocking it till they melted away. They brought back the equipment for further tests, instead of leaving it on the moon. Just before landing, the battery on the ascent stage of the Lunar Module was not found in order. Luckily, it was soon back to normal.

As Shepard and Edgar Mitchell prepared to come out of the Lunar Module, there were communication problems in the suit. The moon walk was delayed by nearly an hour. And then came the eagerly expected moment. For the first time, there was live colour television from the moon. Against a black horizon, the Lunar Module and the astronauts appeared white, while the surface varied from green-grey to light blue-grey.

The scientific instruments they left behind analysed the lunar dust, recorded the tremors on the moon, both natural and man-made, examined the protons and electrons arriving on the moon from the sun and the stars and detected the gases, escaping from the moon's interior or rocks. The findings were transmitted to the earth by way of different radio signals.

A Lunar Cart

For the first time, the astronauts had taken with them a two-wheeled cart to transport cameras and rocks. As in the previous mission, they set up an experiment package 300 metres from the Lunar Module, they walked up to a small crater called Doublet to set up the instruments. They complained of the soil which came up to the top of the footpad. Like sprinters seen in slow motion films, they moved about and bagged



Pathways to the Unknown: track marks of the moon-cart used by the Apollo-14 astronauts

a rich collection of rocks, including two foot-ball sized specimens. When they returned to the Lunar Module, they had 30 minutes of oxygen left in their moon-suits. But Mitchell's suit was leaking oxygen. There were doubts that the second moon-walk would have to be cut short. As the mission control began working on the problem, the astronauts went

to sleep. Their colleague, Stuart Roosa, aboard the commandship circling them above, also went to 'bed'.

Though people on the earth passed one night, it was still dawn on the lunar surface, with a temperature of 50° Centigrade outside. The oxygen leak problem was found to be minor. This time they had taken hoses to connect their suits so that two men could draw oxygen from one system. The astronauts were allowed to come out of the Lunar Module earlier than planned to begin their second moon walk.

The Receding Crater

The astronauts started for a crater called Cone. Unlike the previous day, when they had found it easy to move about in the one-sixth gravity of the moon, they were soon tired, as they climbed their way amidst craters and boulders towards the rim of the Cone crater. They had covered two-thirds of the way, but were soon gasping for breath. They found the crater receding farther and farther, as they walked towards it. Their heart beat went up to 150 a minute and mission control ordered them to turn back. They were then 914 metres away from the Lunar Module. Indeed, they found the life-support system on the back, heavier than expected. All this shows that man has yet to know the effect of one-sixth gravity on the moon. Thus ended man's first attempt at mountaineering on the moon.

The two men were outside the Lunar Module for over four hours. However, the rock collection was successful. They photographed and described the rocks before picking them up. The rocks from the Fra Mauro area, named after a monk in the middle ages, were described as unique. The surface is believed to have been covered by the moon's most ancient rocks, which may have come from great depths, following a meteoroid's impact on the moon to form the large Sea of Showers (Mare Imbrium). Scientists hope to find rocks older than four thousand and five hundred million years.

Shots on the Moon

The rocks do not tell the entire story. Hence, several scientific in-

struments were deployed by the astronauts. Mitchell did a new experiment. After laying out geophones—seismic listening posts—in a line at set intervals, Mitchell used a stick-like device called the thumper to fire shots on the moon. The seismic waves were recorded by the geophones. He had left behind a grenade launcher which could be fired later from the earth. These experiments would help scientists to know about the internal structure of the moon. They had obtained a core sample after digging into the surface.

Experiments in Zero-gravity

After a stay of thirty-three and a half hours on the moon, the return journey began and it was trouble-free. The long period of zero-gravity was utilised by the astronauts to make some experiments. In conditions of perfect vacuum and weightlessness, metals behave differently. Metal hairs and viscose fibres were fixed in a heat capsule and then cooled to solidify into a new metal. New metal alloys and new types of glass are thus envisaged.

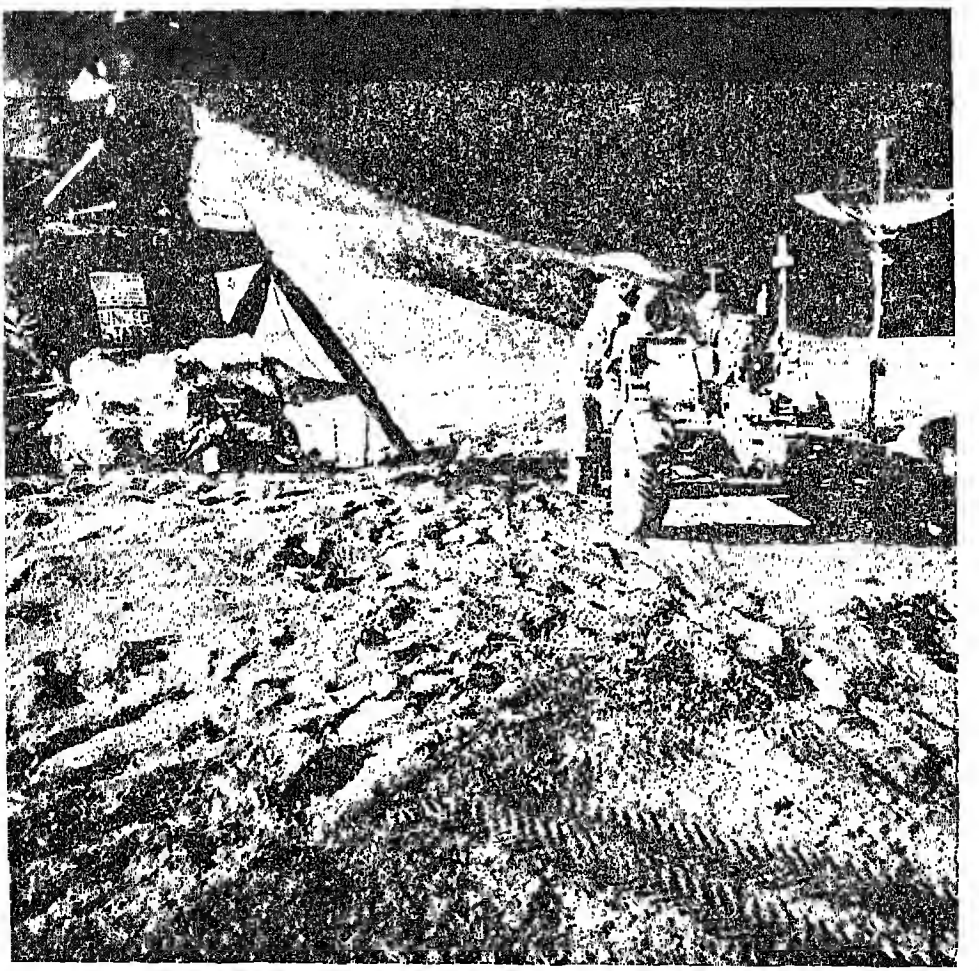
The Moon Drive

In the next mission, man took a vehicle to the moon, called Lunar Rover.

The Hadley-Apennine area where astronauts David Scott and James Irwin landed in the Apollo-15 mission, is a geologist's paradise. It was a plain, cut out by a large gorge that runs along the base of some of the highest mountains on the moon. The Appennines are 4,000 metres high and the Hadley Rille is 360 metres deep. The landing area was 748 kilometres away from the equator, whereas all the earlier astronauts had landed within 112 kilometres of the equator. North-west of the landing site is the largest circular base on the moon—the Sea of Rains. Some of the rocks in the landing area might have been thrown from the 'Sea of Rains'. The most mysterious feature of the area is the rille. No one knows for certain how it was formed.

The Rover was a four-wheel vehicle, which could work on even two wheels. Each wheel was powered by a separate battery. The top

speed of the one-horse power vehicle was stated to be 10 kmh. But in fact, its speed averaged 8 kmh. on the first day and 10 to 11 kmh. on the second. The 310 cm. long and 183 cm. wide vehicle weighed



Motoring on the Moon (Apollo-15 mission), actual scene as televised from the moon

209 kg. on the earth, while on the moon its weight was only 35 kg. It rode over 30 cm. high rocks and climbed about 25° slope. Its centre of gravity was so low that it did not overturn. On the first day, the 'buggy' lost half its steering capacity, as its front wheels went out of order. Driving it on two wheels was like steering a boat for the astronauts. An important feature of the rover is its computer, which told them their location. Without it the astronauts would find it difficult to return to their landing craft, as the landmarks on the moon are often misleading. The vehicle also had a TV camera, that worked whenever it was not on the move. The camera could also be controlled by radio command from the earth.

On July 31, 1971, Scott and Irwin became the first men to drive on the moon. Millions of television viewers saw the moving pictures of the craters, pockmarked slopes, with the peak in the distance. The drive came two hours after they became the seventh and eighth human beings to step out on the moon. They photographed the rille and scooped up the lunar material. The first excursion lasted six hours, an hour less than planned.

Next day the excited explorers drove their buggy to the base of the mountain and collected rocks and soil samples that might date back to the beginning of the solar system. On the second day, they had better luck as all the four wheels worked. They travelled six kilometres away from the lunar module Falcon.

Original Rock

There was however a pleasant surprise for him. He found a foot-ball sized rock, something close to Anorthosite, a rock that is part of the original lunar crust. Besides this, the treasure included samples of bedrock lying just beneath the moon's surface, sections from layers on the wall of Hadley and pictures of cinder cones in a corner of the Sea of Serenity. The cinder cones were sighted by Alfred Worden, the Command Module pilot, who remained in lunar orbit while his colleagues were on the moon. The cinders could mean that the moon had volcanic eruptions for a full thousand million years later than previously thought.

On the third and final excursion on the following day, they drove to the edge of the deep Rille and gathered rocks from its wall.

Heat Flow Experiment

The heat flow experiment, which was done for the first time, consisted of drilling two holes to a depth of three metres and placing electronic thermometers inside. It took more force than expected to operate the drill, which weighed very much less there. They expected loose soil for five metres down the surface but after just one metre, they found it hard to drill further. However, they succeeded in obtaining a core sample from a depth of three metres in one of the places.

The thermal make-up of the Hadley region seems to be quite interesting. While the surface has a temperature of 73° C, it was —21° C just 50 cm. below.

Among the other instruments left behind on the moon, was a laser reflector consisting of 300 quartz cubes. Earlier reflectors had only a hundred cubes. A dust detector told scientists the rate of accumulation of 'dust' on the moon and how it affected the temperature there. This would give data necessary for designing buildings and vehicles on the moon. A suprathermal ion detector reported on 'positive ions' close to lunar surface. A cold cathode ionization gauge searched for a lunar atmosphere. Even one molecule in a cubic kilometre would be a discovery!

Another important instrument left on the moon was the magnetometer. It investigated how the structure of the moon, particularly its electrical property, reacts to the solar wind and its magnetic property. Tentatively, it is claimed that there is an outer layer of the moon, which poorly conducts electricity, followed by a highly conducting shell inside, besides a mantle. Thus, magnetic readings apparently tell much about the internal structure of the moon.

Before leaving, Scott paid homage to Galileo by dropping a feather and a hammer. They hit the ground at the same time, proving Galileo right.

Astronaut Worden circled the moon alone in the Command Ship Endeavour'.

After 67 hours' stay on the moon, the Apollo-15 astronauts blasted off to rejoin the Command Module. For the first time, the lift-off was televised live from the moon, by the camera left behind by the astronauts.

David Scott setting up Experiments on the Moon

A Mini-Satellite

While in lunar orbit, the astronauts released a 36 kg mini-satellite from the Service Module. This was the first time that man launched a satellite from lunar orbit. It went round the moon at four kilometres an hour, in a 112-kilometre high near-circular orbit.

The mini-satellite had three experiments. One was called S-Band transponder experiment. This would examine the **mascons,** those unknown lunar areas which exert an unpredictable influence on the orbits of a lunar satellite. One such mascon near the landing site was said to be responsible for a slight off-the-mark touch-down of Apollo-15. The other two experiments from the mini-satellite were designed to throw more light on the earth's magnetic field.

The Service Module also carried several scientific instruments in this mission. They included a mapping camera which can take pictures of the stars, a laser altimeter that tells the distance from the spacecraft, and an X-ray spectrometer that can measure the elements which form the rocks.

The used film from the Service Module was recovered by Alfred Worden, who did a 'space-walk' to do so. This was man's first walk in deep space, at a distance of 3,20,000 kilometres from the earth. His 'walk' lasted 17 minutes. Wearing a pressure suit and attached to a 8-meter-long life-line, Worden came out of the Command Module and got back the film cassettes. They contained 3.2 kilometres of high-resolution film covering nearly 20 per cent of the moon.

Though there were minor troubles, the Apollo-15 mission went off smoothly. Just before splashdown, one of the three parachutes failed. The impact velocity was 10.7 metres a second as compared with eight and a half metres a second when all three parachutes are open. Unlike the previous missions, there was no quarantine this time, as the moon samples were not considered dangerous.

What surprised observers was the long time taken by the Apollo-15 astronauts to become normal. It took almost 72 hours after their 12-day expedition ended. Both Scott and Irwin experienced irregular heart-beats while on the moon. They were very tired and spent more energy than expected for their work. Irwin also suffered from dizziness.

An interesting phenomenon observed by the astronauts is believed to be cosmic rays. They put on blind-folds but described brilliant streaks of light. They reported 60 flashes an hour. It is not known whether the flashes were a sensation, felt by the brain's optical nerves, or true light. If it is the latter, it would not prove dangerous. But if the rays hit the cells, they may destroy them over a long period of exposure.

A Three-day Quest

Apollo-16 was the penultimate trip to the moon by the American astronauts. John W. Young, Commander, and Charles M. Duke, Lunar Module pilot, stayed on the moon for a record 71 hours and also set up an endurance record for moon-walkers.

The touch-down was in a plain within a rugged highland region named Descartes, after the 17th century French mathematician. The site was 300 kilometres south of lunar equator and is believed to contain volcanic rocks aged between 3,500 and 4,600 million years. Descartes is part of an area that comprises about 80 per cent of the moon's surface.

The primary quest of the astronauts was for volcanic remnants and ancient rocks. They even turned over boulders and searched for unusual rocks. They found two intriguing white pieces. One of their priorities was an uphill trip to Stone Mountain, a 506-metre peak. They drove in their electric car 250 metres up the hill. Scientists believe that the hill was formed by a thick lava flow during the convulsive formative years of the moon.

The astronauts, Young and Duke, also drove to a deep bright crater, called North Ray, during their third and final excursion. The crater is noted for its layers of rocks on the sides with a lava bed in the centre. The crater is believed to have been gouged out of a mountain base long ago.

They collected in all one hundred and eleven kilograms of rock pieces and samples—22 kilograms more than planned. Most of the rocks were found to be breccias, made up from several kinds of material melted together. Some, however, are expected to be part of the original lunar crust. Surprisingly, they did not find many purely volcanic

crystalline material, as expected. But scientists hope to find evidence of the early volcanic process.

Top Speed

Their drive on the moon, watched live on TV by the people on the earth, was noted for its speed. They reached the top speed of 17 kmh., though at times they could go only at 5 kmh., especially among boulders. The speed was more than that reached by the Apollo-15 men. In all, they drove about 25 kilometres. Several times, the vehicle bounced completely off the ground.

The astronauts complained of dust and they had to dust each other off! But they were quite cheerful. During the final minutes on the moon, they jumped about. Duke fell down but got up safely!

As in the previous missions, the astronauts set up a nuclear-powered automatic scientific station. It was the fourth such robot installed there. Among the new experiments was a miniature astronomical observatory. It could photograph 10,000 celestial objects including the earth. The advantage is that it is free from the atmospheric or magnetic interference that hinders such experiments near the earth. The instrument will also detect clouds of hydrogen, the most abundant element in the universe. Young adjusted the ultra-violet camera towards the earth and photographed a huge hydrogen cloud surrounding the home planet.

Another new experiment was designed to detect cosmic rays. It was mounted outside the moon-landing craft. Cosmic rays are in fact atomic particles travelling at about the speed of light. The earth's magnetic field deflects them. On the moon, where there is hardly any magnetic field, cosmic rays leave trails in the detector.

Biological Specimens

The effect of cosmic particles on some forms of life was also studied. Dormant biological specimens, including seeds, spores, plant embryos and shrimp eggs were put in a stack in the command ship. The idea was to see if cosmic rays induce mutations or cause other changes in

their cells. In another experiment, millions of bacteria, viruses and fungi were exposed outside the command ship for ten minutes, to the conditions outside. It was done by Thomas Mattingly, the Command Module pilot, when he 'walked' in space to recover the film casettes mounted outside the spacecraft.

The mission was not all perfect. There were some disappointments too. Young snapped a cable connecting the heat flow experiment. Repairing it was ruled out as too delicate an operation. This experiment was designed to see if the moon had a molten core, or if the heat was of radio-active origin. The Apollo-15 instrument had indicated that the moon's temperature is higher than anticipated. Experts are of the view that below one metre, the moon's temperature increases by one degree per foot. There is also no big diurnal variation. The heat flow from the interior is estimated to be one-fifth that of the earth. These are yet to be confirmed by more experiments.

Another experiment that failed related to the Lunar Module after the astronauts transferred themselves to the command ship. The Lunar Module tumbled out of control, instead of crashing on the moon. Such a crash would have given data on how the seismic waves were conducted by the moon. It has been calculated by the earlier experiments that the velocity of the seismic waves gradually increases till a depth of 24 kilometres but from there onwards, there is a sharp increase, possibly because of very dense material.

The mission was cut short by one day, because of the failure in a back-up control device in the rocket of the mother-ship, which earlier almost cancelled the moon landing. The research satellite launched by them in lunar orbit, could be fired only from a less favourable orbit than foreseen.

Man has landed on the moon six times. Each time, he improved his performance, in terms of the time spent outside the moon-lander, the surface distance travelled and the weight of the sample obtained,

as shown by the following table:

	Time spent outside LM (hr.	min.)	Distance covered (km.)	Samples Returned (kg.)
Apollo 11	2	24	.25	20.7
Apollo 12	7	29	2.00	34.1
Apollo 14	9	23	3.30	42.8
Apollo 15	18	33	27.90	76.8
Apollo 16	19		25.00	111.0
Apollo 17	22	5	34.40	125.0

The Final Mission

The final mission in December 1972, Apollo-17, was the most successful of the series. It lasted nearly thirteen days, the astronauts carried out more scientific experiments than before. The only major snag came a few seconds before lift-off, when a computer automatically switched off the launch sequence. The fault was located and set right after nearly two hours.

The crew included for the first time a practising geologist, Dr. Harrison H. Schmitt. Heading the mission was Eugene A. Cernan, a space veteran. The third man was Ronald E. Evans of the command ship.

An important task of the crew was the setting up of the sixth automated research station, which would send lunar data to earth. It included a gravimeter, which was to measure the gravitational attraction of the earth on the moon, and detect gravitational radiation from cosmic source, if any. Another was an electronic search for water, with an instrument that measures the physical properties of the lunar interior down to one kilometre. A transmitter sends radio signals into lunar surface and the timing and strength of the radio signals should indicate if water or ice is hidden somewhere. Electronic signals were sent from the command ship, orbiting the moon, and the returning echoes were

photographed on a television screen to know the interior region. Yet another instrument comprised an ultra-violet spectrometer and a mass spectrometer, to identify the constituents of the thin lunar atmosphere and could detect oxygen, in case it is there. In a separate experiment, the scientists wanted to find out the amount of radio-activity, deep beneath the surface. They know that heat from the core is flowing towards the surface. The heat flow experiment gave rather high readings for two metres below the surface.

Soon after they went into orbit, Schmitt reported seeing a mysterious flash near a crater below. No such active event was seen before.

The landing site, named after Taurus mountains and Littrow crater was a combination of mountainous highlands and lowland valleys in the northern hemisphere of the moon.

Orange Moon

A startling discovery made by Cernan and Schmitt in the area was a volcanic-looking orange soil. This could be the result of vapours steaming from the interior, perhaps one billion years ago in a volcanic gasp. Later, while orbiting the moon also, the astronauts spotted a mysterious path of rusty-hued craters in the moon's Sea of Serenity. One of them exclaimed that he had found an orange moon!

The two astronauts set up many records. They were on the moon for 75 hours, and spent 22 hours 5 minutes and 7 seconds, walking and motoring on the surface. The longest single moon-walking period lasted 7 hours, 37 minutes and 22 seconds. The top speed of their moon car reached 18 kmh., covering a distance of 34.4 kilometres. They collected lunar samples weighing 125 kg. which included some of the oldest and youngest moon rocks.

As the scientists watched them on television, Cernan and Schmitt bounced on lunar slopes, chipping off boulders coated with glass, looking like ice-bergs floating of a grey dead sea, while the mountains looked as if covered with fur.

After re-joining the mothership, the Lunar Module was sent crash-

ing at 900 kph. on the moons surface. Its impact could not be televised, as it landed 15 kilometres away from the recording instruments.

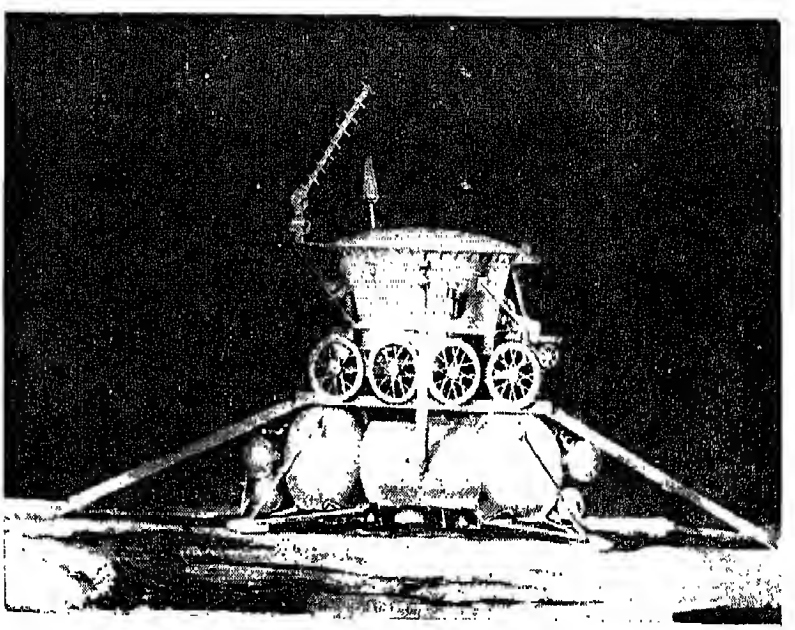
Besides the astronauts, six tiny mice also travelled with them to the moon. They remained in the Command Module. The idea was to determine if heavy cosmic ray particles can injure the eyes and brain of the mice. One of them was found dead on its return.

Before the astronauts left the moon, they placed a plaque reading "May the spirit of peace in which we come be reflected in the lives of all mankind."

As the Apollo era ended with a perfect splash-down, after a 302-hour mission, the earth seen from the moon as a blue crescent in a black sky, acquired greater importance. After all, the earth is a lovely place, full of life, unlike the desolate moon. Developing countries like India hope that the technology which put men on the moon, would now pave the way for a better life for the world's less privileged people.

Work of Robots

LIKE a battery-operated toy train, a vehicle on the moon moved at the flick of a switch on the earth. Its name was Lunokhod-1, an eight-wheeled moon buggy, resembling a bath-tub. It rolled out of the unmanned Soviet probe Luna 17, which soft-landed on the moon on Nov-



Lunokhod on top of Luna-17 on the Moon

ember 17, 1970. This was yet another space first, achieved by the Soviet Union. The wheel, which revolutionised life on the earth, has reached the moon. The selection of the wheel to carry man's first vehicle on the moon, is no accident. In prolonged experiments, different modes of motion were tried, including crawling like a caterpillar, leaping, jumping and 'walking'. Only the wheel was found suitable.

The place where Lunokhod-1 landed is of great scientific interest. It is called Sea of Rains (Mare Imbrium). It is 1,040 kilometres wide and is believed to have been formed as a result of collision by a big meteoroid in the past. There is apparently some dense material inside the area, which exerts a slight pull on a spacecraft above it.

Moscow television showed the testing of the vehicle on ground under conditions resembling those on the moon. If the buggy got stuck up in a crevice, it automatically stopped. If it felt it would roll down a cliff, it again halted. This was necessary, since it took two to three seconds for the signals to travel from and to the moon, during which the vehicle would be on its own. The problem was the size and weight of the vehicle, which had to be carried in a particular type of rocket. The extreme temperature variations on the moon and its vacuum demanded unusual alloys, lubricants and materials. It was disclosed that the electric motor for the buggy were first tested in the Luna-12 mission and later in open space, in Luna-14.

The moon buggy carried three television cameras, two for steering it and one for taking photographs. The panoramic pictures received from it were helpful to make a new map of the area and understand the terrain better.

The energy for the buggy came from the sun. The solar panels on the top of the vehicle charged the batteries during the long lunar day, which lasts as long as 14 earth days. Some twenty layers of foil, with glass wool in between, protected the engine from the extreme heat and cold. While the temperature outside goes down to $-130°C$ in the lunar night (which is again equal to 14 earth days), the temperature inside the vehicle stayed at a reasonable 15°C. All the eight wheels made of

wire mesh were independently driven. During the cold night, a nuclear heat source warmed the air circulating inside and kept the parts in working condition.

Work and Hibernate!

In the first five days after its landing, the moon buggy covered 197 metres before settling down for the fortnight-long night. Ten communication sessions were held with it by the ground crew during this period. An average communication session lasted four hours, when the Soviet Union and the Sea of Rains were in direct line of sight. A crew of five was in charge of the operations. It emerged from its 'hibernation' on December 8 Tests showed everything was in order. It then began its second patrol. This time it went about in the second gear for nine hours, which was used only for a few minutes earlier. It also analysed the mechanical properties on the moon soil. During its 'sleep' also, ground control 'talked' to it.

By the time the self-propelled vehicle went into hibernation again on December 22, it had covered 1,719 metres, on the surface. It was then 1,370 metres away from the landing stage. Ground controllers selected a crater for its rest. It was 100 metres wide, with a slope of 10 degrees steep. It then crawled inside and called it a day. When it woke up, a new assignment was waiting for it. It was asked to go back to its mothership. The buggy crawled out and took a somewhat new route.

An interesting feature of the movement was its capacity to negotiate the craters on the moon, some of which are 20 metres wide and 15° steep. At one point, it went down a crater 16 metres wide and two metres deep and climbed out. It tilted forward 27° and leaned 17° to the side.

Back on Its Own Track

In other experiment, the earthly drivers of the moon jeep decided to bring it back along its own old track. After hours of adjustment, its

television showed the rugged track left by it a month earlier. As it chugged along the beaten track, it showed the landing stage and the earth in the background! This experiment is of great significance, as samples from the moon can be obtained from distant places in the future. The track left by the vehicle was some sort of a scale rule for the navigators.

The moon buggy carried a French-made laser reflector. Pencil-thin beams of intense light rays were focussed on it from France and the Soviet Union. This helped in determining the exact distance between two points with fantastic accuracy. The method could also be used to study the movement of artificial satellites of the moon. Soviet engineers devised a special heat exchange system to protect the reflectors' prisms.

Chemical analysis of the lunar soil was done by an instrument called **Rifma**, short for Roentgen Isotope Fluorescent Method. It irradiates the area of study with X-rays. The resulting radiation from the soil or rock is then registered and the relevant chemical element is identified. The composition of the rock is thus indicated. The density of the soil was also measured as the buggy moved on, by a device called the "ninth wheel".

The instruments registered the solar radiation striking the moon. On December 12-13, 1970, the level of radiation was found a little higher. Two days earlier, there was a solar flare. Its findings of X-ray and cosmic radiation tallied with those of Mars-2 and -3 inter-planetary stations.

In the first two months of its stay on the moon, Lunokhod-1 had covered 3,184 metres. It was not a question of simply travelling. In that case, it would have gone on further. It did a lot of zig-zag turn-abouts like fancy car driving. One of the interesting programmes drawn up for the vehicle was on the eighth lunar day. It was the entry into a new region. Lunokhod-1 covered 1,560 metres first in the north-western and then in the north-eastern direction, at times going across the slope of an old crater.

In early October 1971, Lunokhod-1 stopped functioning, because its nuclear warming device could no longer function. Its active life ended on October 4, after 322 terrestrial days. It covered 10,540 metres, analys-

ed the soil at more than 500 points, and sent back over 20,000 detailed pictures of lunar surface. It had functioned longer than expected. The vehicle has been left in a position in which its laser mirrors can still be made use of.

Future Lunokhods

It paves the way for mobile moon laboratories and instruments set up by robots. They could go to the lip of a yawning crater or the tip of a dizzy peak on the moon without any risk. The vehicles could also go to the hidden side of the moon and with a communication satellite placed in moon orbit, perform there also. In the near future, the buggy may get long arms and tools to seize a rock and crush it. It could then race back to the mothership for transfer to the earth though Luna-17 had no return rocket.

Such automatic probes could land on Mercury, Venus, Mars and other planets. Wherever it is feasible, they would be scouts for man.

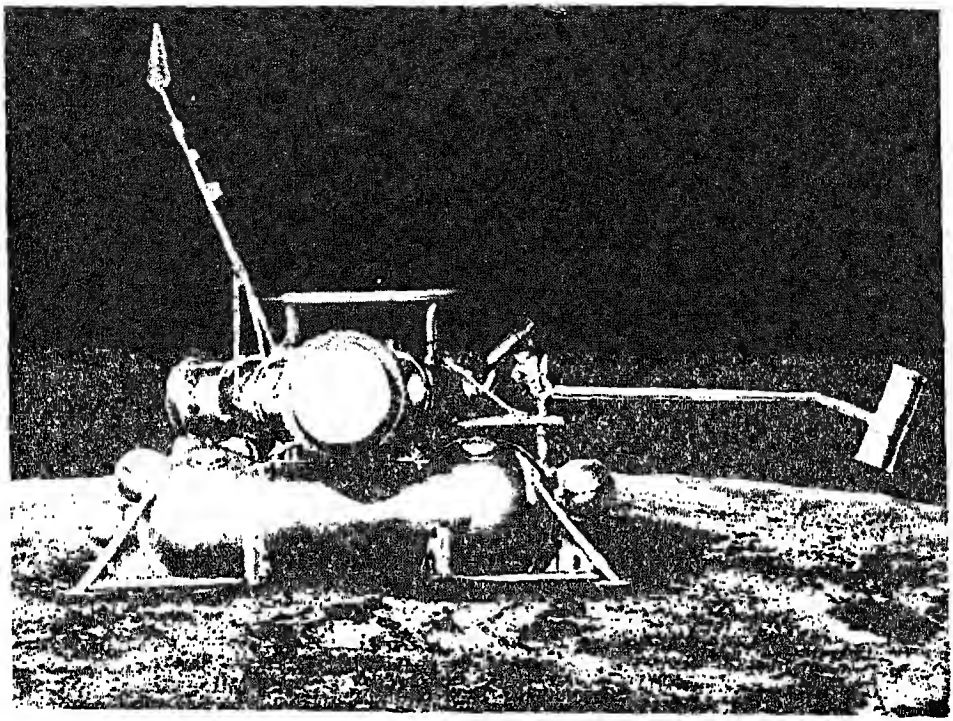
Lunokhods may in the future operate during the night also, by having a better nuclear power system on board. They may have facilities to process the data on soil analysis on the spot. They may have more advanced TV cameras, which would beam the image continuously. Their computer may be improvised to take in commands for a longer time—a factor useful in probes on distant planets. In short, Lunokhod-1 has done a pioneering work of great significance to the unmanned exploration of space.

A Robot Brings Moon Dust

The moon buggy assumes added importance because of another equally important achievement accomplished earlier by Luna-16. It brought back to the earth moon samples, the first to do so automatically.

Launched on September 12, 1970, Luna-16 had additional equipment. It included a device to drill moon rocks, a rocket to bring them to the earth and a container which could be recovered.

Luna-16 first went into a circular orbit of the moon. Its trajectory was corrected so that it could break off from a particular point. The



A Robot in Action : Luna-16, which dug out Moon Soil

orbit became elliptical with the lowest point coming within 16 kilometres of the surface. On September 20, it soft-landed, when it was night on the moon. The main rocket worked up to 600 metres from the surface and from a height of 20 metres, smaller retro-rockets took over, dropping Luna-16 gently and precisely on the moon. The soft-landing of the 1,880 kilogram probe was monitored by observatories in Britain and West Germany.

The place where Luna-16 landed was the Sea of Fertility on the eastern edge of the moon. Earlier probes had landed on the western side in the Ocean of Storms. Thus, the area was not studied by man earlier by landing probes.

On a command from the earth, an electrically-operated device started drilling the moon's surface. The density of the rocks was simultaneously measured. The speed of the drilling was controlled from the earth. The depth reached was 35 centimetres. On completion, the drilling rig was separated and the drill containing the rock was placed in a container, which was closed hermetically.

On September 21, another command from the earth was flashed and the rocket lifted off the moon—the first robot to do so. The landing stage served as the launch pad. When it reached a speed of about 2,708 metres a second, its engine was switched off and the rocket began its homeward journey. Three days later, the speed increased to eleven kilometres a second and the recoverable part with the moon rock separated from the rocket. When it was eleven kilometres from the ground, the main parachutes opened and brought it down the steppes of Kazakhstan. It could be sighted from a height of 2,000 metres.

The moon dust, weighing about 85 grams, was brought to a special laboratory, where it was put in quarantine. Special care was taken to see that the moon dust was not contaminated by the earth's atmosphere or water. It was photographed at different light intensities. It was also magnified and recorded. Chemical, physical and radiation tests were made.

The moon dust, according to the Soviet newspaper *Izvestia,* looked grey brown but under light, appeared greenish with a touch of red. It was estimated to be between 2,000 and 3,500 million years old. In fact, lunar dust is older than this, its age being put at 4,500 million years.

The success of Luna-16 makes it possible for similar spacecraft to fly to other planets and automatically recover samples from there. Britain's leading astronomer, Sir Bernard Lovell, said that Luna-16 opened the possibility of automatic recovery of Martian samples during this decade.

This fact also brings that day nearer when an automatic observatory could be set up on the moon.

In the Highlands

Two-thirds of the lunar terrain consist of highlands. Having explored the plains, it was but natural to send robots to the highlands.

Towards this objective, the Soviet Union sent Luna-18 in September 1971. After 54 lunar orbits, it crashed in a highland area, near the edge of Sea of Fertility. Luna-19 was sent in October. It entered the orbit of the moon at 140 kilometres distance and later it was brought nearer to the surface.

The next mission, Luna-20, repeated the performance of Luna-16 but brought back to the earth lunar samples from a highland area. It started on a slow journey towards the moon on February 14, 1972. After 105 hours, it orbited the moon on a 100 km—21 km elliptical path. On February 21, it soft-landed on a mountainous area, north-east of the Sea of Fertility. Its television camera showed the surface to the earth. Scientists at home then selected the point for digging the samples. The drilling was done in stages. On February 23, the order to return was given and the spacecraft blasted off from the moon. Two days later, its return portion soft-landed in the Soviet Union, after entering the atmosphere at escape velocity speed. Despite heavy rain and snow in the landing sites, the lunar samples were safely recovered.

Twice the Soviet Union has obtained lunar samples by sending robots. A Soviet expert says, it is not necessary to send a man to the moon for the present. The success of the two lunar spacecraft that brought the samples augurs well for future space exploration.

Some 'Lunatic' Ideas

Man went to the moon thinking it was the cleanest place he might find in the Universe. But the presence of germs on Surveyor-3 has raised several questions. As more and more man-made objects hit the moon, the search for a 'clean' moon is likely to begin in the near future!

While scientists are delighted that the moon has no atmosphere and hence a good piece for study, others want to rob the pleasure and curiosity by proposing to give the moon the air it now lacks. Businessmen also have some designs. The complete vacuum on the moon is ideal for making electronic goods. Factories, with all their by-products of waste, may one day be shipped to the moon. A scientist offers the moon as the way out to solve the ever-growing power needs of man. He wants to convert the moon as a power plant capturing

maximum sunlight. Another scientist says vegetables will yield more on the moon, obviously assuming that there would be people on a lunar colony awaiting their daily fresh quota from the garden. Lest the non-vegetarians should come away from the moon, a biologist has suggested novel methods of sending cattle to the moon! Even if water were not found, engineers say that the moon rocks can be squeezed to get water. But the most curious suggestion is to convert the moon into a waste paper basket, by blasting big holes in it with the help of nuclear energy and sending all the earthly waste. No one knows how things will shape. We are indeed lucky to see the moon in its pristine glory!

Tales from a Grandma

THE moon was a silent witness to the evolution of life on the earth. With no air or surface water, the moon has preserved the rocks that were formed in the beginning of the solar system five thousand million years ago. This evidence on earth has been wiped out by volcanoes, winds and mountains. The moon is like a grandma who can tell us stories of the old days.

Before we hear them, let us see how the grandma got there. Some say part of the earth was once thrown away and wound up as a moon. Others maintain that the moon was formed elsewhere in the solar system but was captured by the earth's gravity. Some others hold that the moon was formed alongside the earth during the birth of the solar system.

The rocks and dust of the moon brought by the astronauts have been examined by hundred of scientists in various countries, including India. The moon material was heated, chilled, hammered, squeezed, magnetised. electrified, bathed in all sorts of chemical solutions and was exposed to radiation.

One major difference in the chemical composition between the earth and the moon rocks is that the lunar material contains large amounts of rare earth elements like chromium, titanium, zirconium and yttrium. All these melt only at extremely high temperature. The scientists are surprised to find that there was very little of elements with low melting

points, such as lead, bismuth, sodium and potassium, which are plentiful in earth rocks. And there was no trace of platinum, gold or silver. This shows that the moon is not a daughter of the earth, ripped off our planet.

Pock-marks

Let us now look at the face of the grandma. How did she get the pock-marks? By volcanoes from within or meteor hits from outside? Scientists have crossed swords with one another on this; the duel is not over.

The Apollo astronauts set up several instruments on the moon, powered by a nuclear heating device. One of them is a seismometer. This records any convulsions on the moon. On an average, it records one moonquake a day, though it is a minor rumble. The instruments show the presence of eleven distinct zones on the moon where moonquakes occur. One of the zones gets the quake exactly once a month, when the moon comes closest to the earth.

A Soviet report has spoken about the interrelation between earthquakes and moonquakes. On March 31, 1969, a strong earthquake struck Egypt and then Japan. A few hours earlier, they photographed a radiance in the centre of the Aristarchus crater.

The deliberate crashing of the upper portion of the Lunar Module also gave new data. The ascent stage hit the moon at a speed of over 5,760 kilometres an hour. They wanted to know how the impact was recorded by the seismometer, set up earlier. The crash sprang a surprise. The bang reverberated for as long as 55 minutes. Such a crash on the earth would have been muffled by water inside. Why did the moon reverberate so long? One answer is that this is because the interior is quite solid to bounce off the echoes.

Scientists are now thinking that the moon may be having a crust, an intermediate layer and a hard core. The shock waves from the crash of the discarded ascent stage of the Apollo-15 Lunar Module reached the seismometer, about 100 kilometres away, within 28 seconds, but took seven minutes to reach the two other seismometres of Apollo-12 and -14, which were some 1,000 kilometres away. The shock waves appar-

ently travelled slowly through the crust. The impact of the third stage of the Saturn Rocket of Apollo-15 was also recorded by the seismometers of Apollo-12 and -14. The data suggested a sudden increase in the velocity of the seismic waves at a depth of 25 kilometres indicating a change in the internal structure of the moon.

The magnetometer set up by the astronauts registered a weak magnetic field. Moon rocks brought back to the earth were also found to be magnetised. A magnetic field means more internal temperature. The inner heat is believed to cause volcanoes and structural changes.

A big meteor crashed on the moon, 142 kilometres north of the Fra Mauro landing site of Apollo-14. It is reported to have dug out a crater about 91 metres across. The shock waves of the impact penetrated deeper than any man-made attempts. Dr. Gary Latham of the United States said the seismic waves changed velocity at about 61 kilometres in depth, indicating the end of the lunar crust and the beginning of a lunar mantle. The lunar crust, he believes, is 61 kilometres thick, about twice as thick as the crust underlying the earth.

The far side of the moon has no 'seas' but the crust there is believed to be thicker than in the visible side. Instruments on board Apollo-15 command ship showed that the difference is about four kilometres.

The venting of certain gases like helium from the moon may account for a thin fleeting lunar ionosphere found by the Apollo-12 instruments. The moon is constantly subjected to the 'solar wind'; 25 particles per second strike one square centimetre. Scientists have found the presence of rare gases, such as helium, argon and xenon in the lunar dust. They are left over by the atomic particles boiling off the sun. The Surveyor-3 camera, lying on the moon's surface for 31 months, was exposed to the solar wind and cosmic rays. The rate of erosion of the rocks was calculated, after finding the tracks of solar particles in the camera's glass. The study of the moon can lead to a better understanding of the sun.

At the Tata Institute

Scientists of the geophysics research group at the Tata Institute of Fundamental Research in Bombay have analysed the lunar samples.

They also used an electron microscope which magnifies the samples up to 30,000 times.

There are two main sources of radiation in space. One is from distant stars in our and other galaxies, called cosmic radiation. The other is from the sun, called solar cosmic rays, which are sporadic and of lower energy. A meteorite loses the record of low energy particles when its outer skin burns up during the entry into our atmosphere. On the other hand, the lunar material preserves all the records of effects due to the lowest energy particles in space.

The charged particles alter the chemical structure of the lunar material along their trails called fossil tracks. After chemical etching the rocks are optically examined.

Some of the changes caused by radiation result in radio-active nuclear material. New nuclear substances have been found. They tell us the time of exposure of the sample, besides some data on the solar and cosmic rays.

It should be noted that the constant impact of meteorities changes and shifts the surface material on the moon. This makes analysis difficult.

Age of the Rocks

The most notable feature about the moon rocks is their age. They are older than any rock found on the earth. The age of the rocks is determined by what is known as potassium-argon dating method. After a rock is formed, the radio-active potassium in the rocks goes on decaying into an inert gas, argon. The extent of the decay shows the age of the rocks. Rocks have also some radio-active uranium. As uranium decays, lead appears as the end product. If there is less uranium in a rock, it is perhaps an old rock.

One interesting finding about the age of the moon samples is the difference between the rocks and the lunar dust. The dust is older than the rocks. Perhaps it was thrown out by meteor hits, from the highlands of the moon. The rocks, which have come from the low-land plains of the moon, are younger. If the dust is 4,400 million years old, rocks range from 3,500 to 4,000 million years in age. One of the rocks

is however calculated to be 4,400 million years old.

The old age of the rocks supports the view that the moon has been a cold place. Otherwise, the rocks would have changed. But the appearance of the rocks heats up the grouned for the cold moon theorists. The Apollo-11 rocks turned out to be igneous, like solidified sponges formed by some heat process. They are porous, which sugggests rocks that had solidified from lava. One possible answer is that once there was lava on the moon but then it cooled off later.

The composition of the lunar rock and soil are different. The soil is a mixture of fragments from a long distance. Its study will throw light on other areas of the moon also. Apollo-11 and -12 and Luna-16 went to the 'sea' areas, and there was evidence of basaltic rock, which indicates that the areas were once covered by floods of liquid at very high temperature.

The lunar rock brought by the Soviet Luna-20 from a highland region differed substantially from the samples brought by Luna-16 from the Sea of Fertility. The bulk of samples are what is known as anorthosite type, an ancient rock variety. While in the Luna-16 low-land sample there was 1 or 2 per cent of anorthosite, there was about 50 to 60 per cent of it in the highland sample.

Apollo-14 samples are important, as they indicate the nature of the moon for the first 8 to 10 kilometres below the surface. Analysis of this and other rocks points out that there was considerable melting on the moon in early days. It produced a crust, which later suffered several meteor impacts. It has been claimed that some liquid was there on the moon for at least a billion years, from 4.5 billion years ago to 3.3 billion years ago.

The ion detectors left behind by the Apollo-12 and -14 astronauts registered sporadic outbursts of water vapour ions (which are electrically charged particles). One of them occured on March 7, 1971, and lasted 12 hours. But some feel that it was only the waste water left behind by the astronauts! There are, no doubt, some traces of hydrogen on the moon, though some scientists say that they are only the effect of the solar wind striking on the moon.

Russian Theory

The Russians say that their moon samples, brought by the robots, are surprisingly similar to those brought by the Americans. But their interpretation is different. Dr. Vinogradov, Soviet geochemist, says the lava from beneath the lunar surface broke through the crust. The U.S. scientists generally believe that this is not possible, as there is no water or steam to force the matter up. The Russian scientist also says that some parts of the meteorites hitting the moon will bounce back and reach the earth. But the Americans say an analysis of the meteorites reaching the earth show them to be different from the moon rocks.

The bright spots and colour changes seen on the moon have led astronomers to claim the presence of active volcanoes. Prof. Nikolai Kozyrev observed the outflow of gases from a crater in 1958 and said that there was volcanic activity. In 1961, he concluded that the crater Aristarchus emitted hydrogen gas.

Some people ask: Why go to the moon when the moon material is already on the earth? It is argued that after a meteorite hit the moon creating the big crater Tycho, the moon material must have escaped the lunar gravity and fallen on the earth. Chemical analysis shows that they cannot be meteorites.

The rocks may contain the missing links in the chain of evolution from matter to the mystery called life. The grandma may not tell the entire. story. But the tales retold would enlighten us on the secrets of nature.

5

THE PLANETS AND BEYOND

I seem to have been like a boy playing on the seashore, now and then finding a smooth pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me.

ISAAC NEWTON

The Solar System

It is generally believed that the solar system was formed four and a half thousand million years ago out of a primordial cloud of hydrogen and helium and other substances. The dense hot gas at the centre of the cloud became the sun, while the other regions gave birth to the planets. The earth condensed into a ball of rock with a radius of 6,400 kilometres. Light rocks piled up forming continents while the area between the continents were ready to receive water, apparently pouring from the interior.

The earth is one of the nine planets bound by the force of gravity. The four inner-most planets—Mercury, Venus, Mars and the earth—are referred to as the terrestrial planets. They are believed to have the same rocky material and iron that make up the most of the planet.

The closest planet to the sun is Mercury. It is less than half the size of the earth. Its nearness to the sun has forbidden rocket probes. Till recently it was believed that Mercury rotates once a year and that one side was always hot, while the other was eternally cold. But radar observations hinted recently that Mercury turns on its axis every 59 days. This was a surprise. Many more fascinating details may be available in the future.

Mercury may not be the nearest planet to the sun. A scientist has claimed that he had evidence to infer a new planetary body less than 150 million kilometres from the sun. It has been named Zoe, meaning

life! At present it is not known up to what stage it has developed.

Venus and Mars which are the other inner planets have been the targets of several rocket probes in recent years.

Unlike the inner planets, the outer planets have large masses but low mean densities. They are however less dense than the earth, as they have mostly hydrogen and helium. A study of Jupiter and Saturn may give us an idea of the primordial matter in the universe. More knowledge of these planets would help us understand our planet better.

Soviet and American scientists have given a theory on the formation of planets. They conclude that the Earth, Moon, Mars and Venus were formed on one and the same principle. They believe that after forming from a gas cloud, the planets went through a process of melting. The decay of uranium and thorium gave the energy for melting. The melting process stopped on the moon 3,500 million years ago. The discovery of anorthosite by Luna-20 and the American astronauts on the moon is given as evidence to this theory. Anorthosite was formed there when lava erupted to the surface more than 3,500 million years ago. Anorthosite was smelted out of the planet's interior region.

The Secrets of Venus

You can spot Venus in the pre-dawn sky. It appears as the third brightest natural object in the sky next only to the sun and the moon. The Chinese called it Taipe—the beautiful white one. The Greeks called Venus Cytherea, image of beauty.. The Romans referred to Venus as the Goddess of Love. Venus has defied astronomers for centuries. The morning star has hidden its secrets amidst radiant white clouds.

The distance between the earth and Venus varies from 39.6 million kilometres to 113.6 million kilometres, because of the nature of the orbits of the two planets. Once every 19 months, an ideal situation comes to launch a spacecraft to Venus. Though Venus is the planet that comes nearest to the earth, very little is known about it. It is only in recent times that its period of rotation round the sun was calculated with precision. It takes 224.7 earth days to complete one orbit of the sun. But it takes 243 times longer than the earth to rotate itself.

Galileo was the first to observe that Venus has phases like the moon. At times, it appears as a crescent moon. The visible disc appears in five different ways. However, unlike Mars, Venus has no seasonal changes.

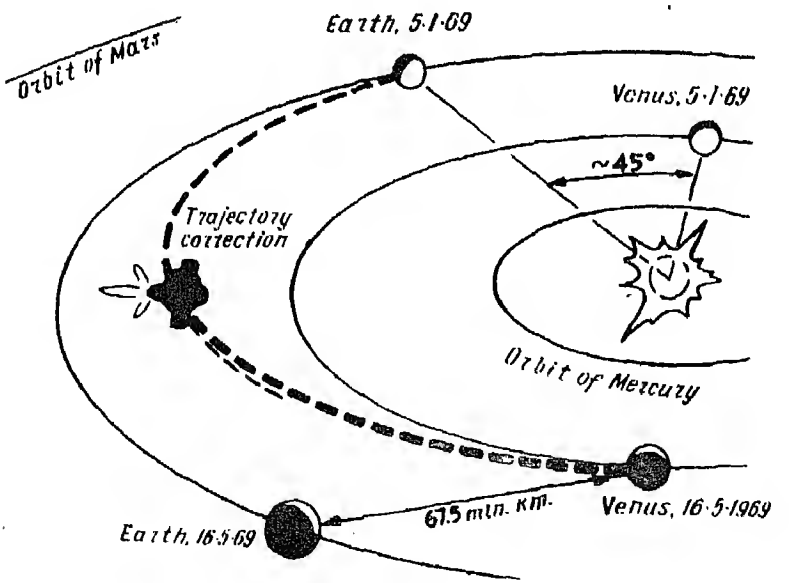
Sunrise in the West ?

A puzzling feature of Venus is its rotation around its axis. While

most of the planets, including the earth, rotate anti-clock-wise, Venus rotates clock-wise. But its journey round the sun is anti-clock-wise. One result of this is that to an observer on Venus, the sun would rise in the west and set in the east! According to one theory, the rotation of Venus will become normal after some thousands of years and cosmic harmony will be restored.

The Differing Sisters

Venus is often referred to as the sister planet of the earth. Their dimensions are similar. It is slightly smaller than the earth in its mass and radius. The diameter of Venus is only 642 kilometres less than that of the earth. Both receive roughly the same amount of sunlight.



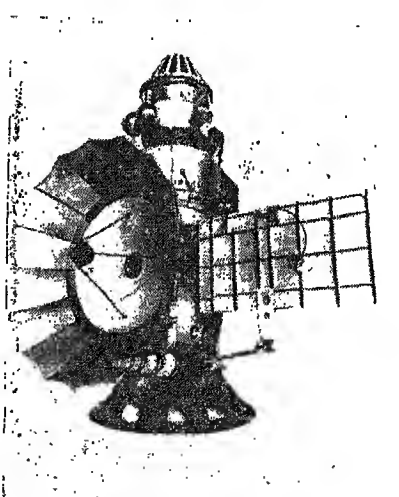
Flight Path of A Venus Probe

The escape velocity is 10.4 kilometres a second for Venus, as against 11.2 kilometres a second for the earth. And yet what a difference between sisters, one a furious inferno and the other a cool, green cradle of life.

Several attempts to send spacecraft to Venus had failed. The Soviet Spacecraft Venus-1 in 1961, missed the planet, and the first Mariner probe of the United States in 1962 also failed. Mariner-2 succeeded in by-passing the planet in 1962. It measured the temperature and the atmosphere of the planet. Russia's next attempt in 1966, Venus-2 also succeeded. It flew past the planet and on March 1, 1966, Venus-3, hit the planet—the first man-made object to do so. In 1967, Venus-4 penetrated its atmosphere and ejected a lander. The same year, America's Mariner-5 flew past the planet at a distance of 4,160 kilometres. The next Soviet attempt was a double launch. On May 16, 1969, Venus-5 successfully parachuted an instrument capsule. It continuously transmitted data for 53 minutes. The instruments measured the temperature, pressure and chemical composition of the planet's atmosphere. One day later, Venus-6 also arrived, entered its atmosphere less than 320 kilometres from the earlier craft and flashed data for 51 minutes.

Soft-landing on the Inferno

A more spectacular achievement was in 1970; Venus-7 soft-landed on the hot surface on December 15. Earlier probes were crushed under the planet's extreme pressure. Launched on August 17, 1970, Venus-7 travelled for 120 days covering a distance of 320 million kilometres. One hundred and twenty-four communication sessions were held to get data on inter-planetary space. Three days before landing, solar batteries on the descent module were charged on command. At first, it was announced that the descending craft sent back data for 35 minutes. After six weeks, the Soviet news agency, Tass,



Venus-7, the Soviet Unmanned Probe

announced that the probe made a soft-landing and sent data from the surface of Venus for 23 minutes. The nature of the signals, though found very weak, was stated to be different from the previous ones. Incidentally, the moon robot Lunokhod-1 was also transmitting data at that time. This was the first time when man-made objects were in contact with the earth simultaneously from two celestial bodies.

In July 1972, Venus-8 automatic probe soft-landed on the planet's sunlit side. During its descent and for 50 minutes after landing it sent data to earth on luminosity, pressure and temperature.

The data obtained by the probes are of course tentative. They may even be completely wrong. Nevertheless, what can be reasonably guessed, appears fascinating.

Venusian Atmosphere

Venus has a very dense atmosphere. Venus-7 reported that the density is 60 times that of the earth. Over 90 per cent of the atmosphere on Venus is carbon-dioxide. The percentage of carbon-dioxide in Venus ranged from 93 to97. About as much carbon-dioxide was emitted by the earth in the distant geological past. But it went into the formation of sedimentary rock. Moreover, plant-life replenished the atmosphere with oxygen.

Venus-4 discovered evidence of oxygen. Free oxygen is considered an index of plants. Some contend that the oxygen is not more than 0.4 per cent. Venus-5 and Venus-6 put it as 0.1 per cent. Also, not more than 2 per cent of nitrogen and some inert gases are believed to be there.

How Hot?

As regards temperature and pressure, Venus-5 and -6 took the readings at about 20 km. above the surface. The temperature at this level was 320°C and the pressure was 27 atmospheres. The temperature went up by 10 degrees for every kilometre. At this rate. the surface ought to be 500°C and the pressure would be 100 times that on the earth. Mariner-5 reported a pressure of 65 atmospheres. Even with oxygen, it would be suffocating. Venus-7 reported a surface temperature of about

475 °C and air pressure 90 times that on the earth at sea level.

There was a slight difference in the temperature readings by Venus-5 and -6. Venus-5 read the surface temperature at 530°C and 140 atmosphere of pressure, while Venus-6 put it at 400°C at 60 atmospheres. Some Soviet scientists explain the variation by saying that the two probes landed at different heights. Does this mean there are mountains on Venus? No one knows at the moment. But the pressure on Venus can crush foreign bodies entering it.

Both Venus-5 and -6 landed on the night side of Venus. There seems to be no difference in temperature between day and night at the poles and equator. This is because of the heat, stored in the atmosphere.

A weak ionosphere has also been detected. It has two peaks of intensity at altitudes of 80 and 96 kilometres respectively. About 1,000 kilometres away, a thin outer layer of hydrogen prevails. This is not as dense as of the earth.

The Cloud Top

The visible cloud top has a radius of about 6,150 kilometres. One analysis says that Venus cannot be solid throughout and must possess a liquid core, like the earth. Otherwise, calculations require that the planet's radius would be more, revealing well outside the cloud cover.

It is not yet known if the clouds are multi-layered or have any features. The lower boundry of the clouds is said to be at a height of 60 kilometres. The clouds must be 5 to 8 kilometres thick. They prevent the heat from escaping the planet's surface. There is a controversy as to whether the clouds are solidified carbon-dioxide or particles of ice. Some scientists say that there may be mercury and magnesium hydrate in the clouds. There are also scientists who will look for some unicellular organisms under the clouds.

Apart from the heat, there is also radiation danger on Venus. The planet has no magnetic field. Particles of high energy from the sun mercilessly strike it. The earth's magnetic field stops such particles, at 50,000 to 80,000 kilometres. On Venus, only its weak ionosphere tries to stop the charged solar particles at about 500 kilometres.

Did It Have Water ?

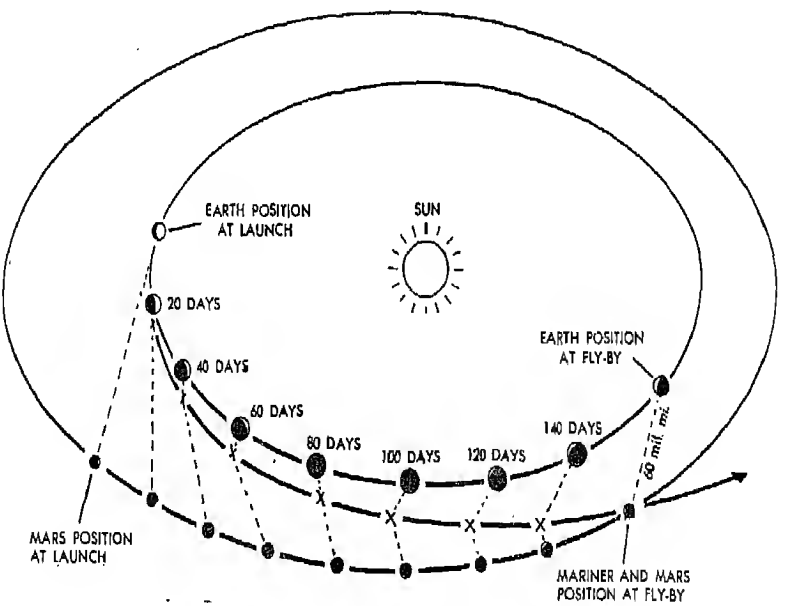
What has happened to water on Venus, if it had any? Under extreme temperatures, water would of course have evaporated. But there is a hope that at higher altitudes, it may be cold enough for water clouds to form. Venus -5 and -6 discovered slightly more water vapour than Venus-4, but not high enough for water clouds to appear.

Direct information on the internal structure of the planet could come only when seismographs are landed on the planet. Theoretical predictions indicate that Venus should show big mountain ranges. Radar readings have revealed irregular features on its surface.

Though we do not know for certain how the planets came to get their shape and atmosphere, there are two opposite views on the stage of evolution reached by Venus. One view that some scientists hold is that Venus lags behind the earth in development by 500 million years. In other words, Venus shows the path travelled by the earth ages ago or gives a mirror image of the earth before plant life changed its atmosphere. On the other hand some predict that Venus is a mirror of the future and warn that one day the earth would lose its oceans and become a wind-swept desert like Venus. More probes are needed to answer the riddles that surround the planet.

The Red Planet

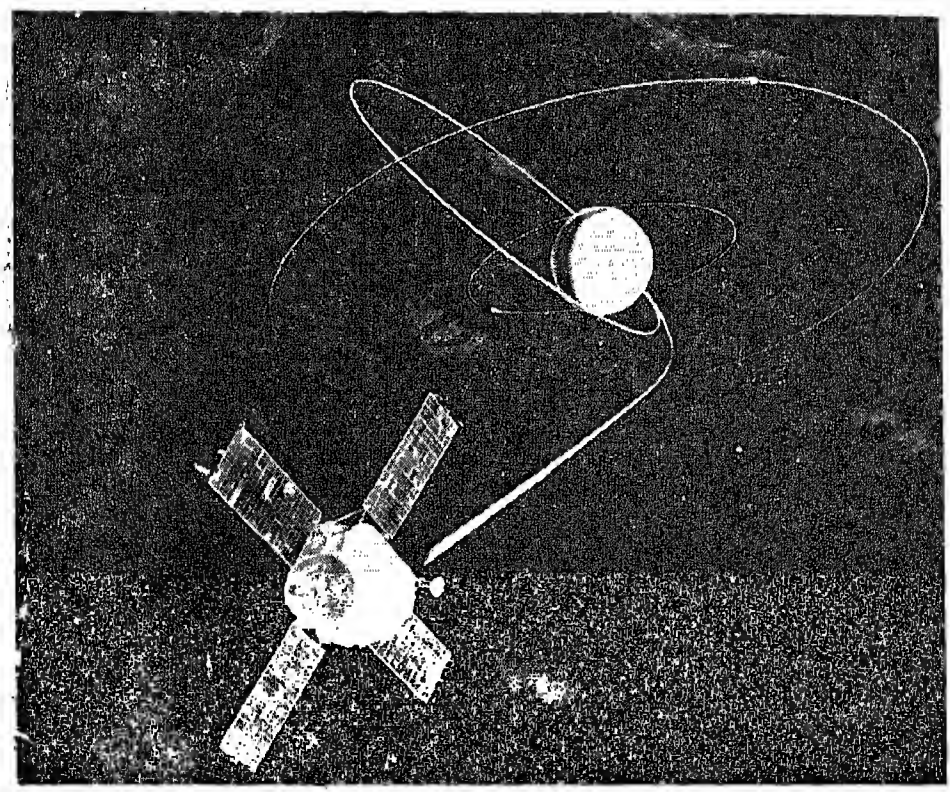
EVEN before telescopes were made, man admired the beauty and mystery of Mars, the red planet. Because of the eccentric orbit of Mars, only once every two years, Mars and Earth come within a distance of 56 million to 102 million kilometres. In 1971, Mars was orbiting at one time 56 million km. from the earth.



Typical Mariner Flight Path To Mars

The period when they are close, is ideal to send spacecraft with the minimum effort.

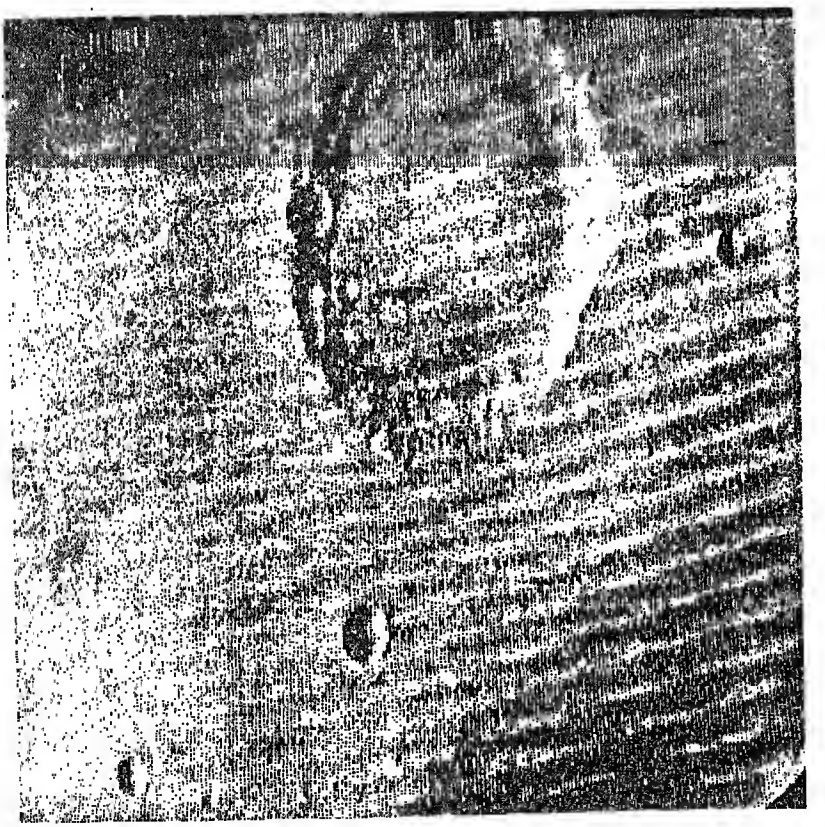
The rare 'launch window' in 1971 was availed of by both the space powers. The United States sent Mariner-9 while the Soviet Union sent Mars-2 and Mars-3. Launched on May 19, 1971, Mars-2 travelled 470 million kilometres and went into Mars orbit on November 27. Five



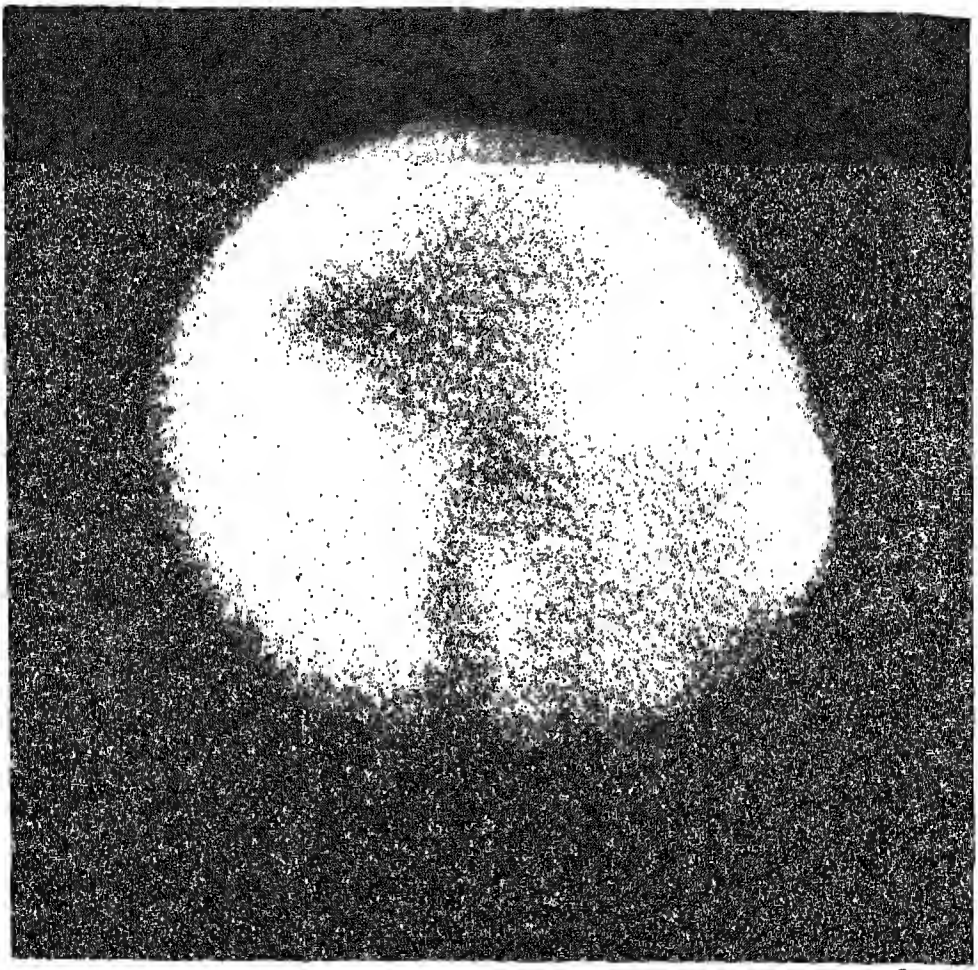
Mariner-9 and its Orbit round Mars. The two mini-moons of Mars are also shown, along with their orbits.

days later, Mars-3 (launched on May 28) started orbiting the red planet. While Mars-2 orbited the planet once every 18 hours, Mars-3 which was farther away, took eleven days to complete an orbit. Mariner-9 was launched on May 31. It came in the wake of unexpected failure of Mariner-8. Mariner-9 began orbiting Mars from November 13.

The first man-made object to go near Mars and send a TV picture of



A View of Mars: a gaping crater with terraced sides, taken by Mariner-6 from 4000 km. Area covered is about 50 km. wide.

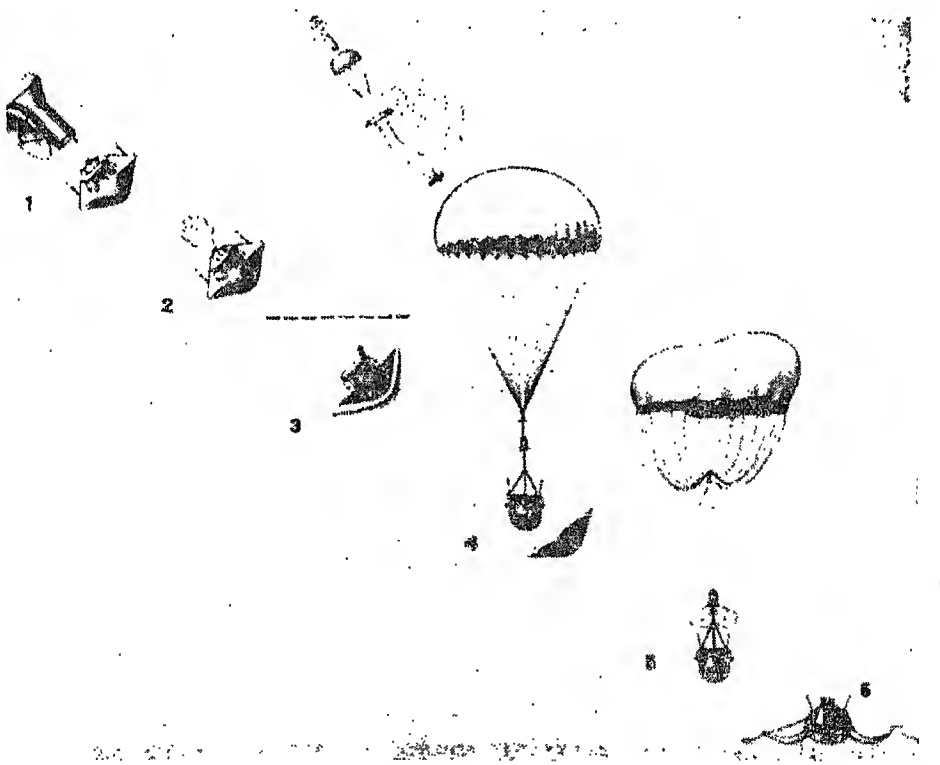


Mars—photographed by the Indian Institute of Astrophysics

it was Mariner-4, launched in 1965. It bypassed Mars within 9,600 kilometres of it. Four years later in 1969, Mariner-6 flew within 3,200 kilometres of the equatorial region of the planet on July 31, after a journey of 156 days covering 388 million kilometres. Mariner-7 went on a shorter

route, covering 315 million kilometres in 130 days. It flew at 3200 kilometers above the south polar cap.

A notable feature of the Soviet probe is the working of a self-correcting mechanism. It takes 15 minutes for the radio commands from the earth to go and return from the spacecraft. That would be too much of a waiting period for a probe near the planet. Hence, the on-board computer calculated the flight path and ordered the probe to correct itself and operated the engine at the right time to slip the craft into orbit. This was achieved after several experiments were made on the ground, simulating the Martian conditions and testing the possible problems.



The Landing Sequence of the automatic Soviet probe on Mars

Mars-2 ejected a capsule on the planet while Mars-3 soft-landed a robot of scientific instruments on the surface, with the aid of a parachute. This is all the more remarkable, as there was a violent storm at a speed of 360 kilometres an hour! Another feature of the mission was that the landing craft did not directly get into touch with the earth. It sent its findings to the mother-craft, Mars-3, which was then in orbit. The mother-craft sent the data at an appropriate time to the earth station. This method saves fuel and is a pointer to similar experiments elsewhere in space missions. However, the television signals from the landed craft faded out after a short while. The storm might have damaged it. Mars-3 started orbiting the planet at a height of 1,380 kilometres, while Mars-2 took a longer path, ranging from 25,000 kilometres to 1,380 kilometres. Besides filming the surface features, instruments on board the craft also studied the temperature, its atmosphere and other features. Mariner has two television cameras, which can spot an object of a 50-metre diameter, besides infra-red and ultra-violet cameras. After the storm subsided, it has radioed clear pictures of the surface giving new information.

The data show that Mars is a living world, geologically quite active. Unlike the moon which has remained almost unchanged, Mars is a changing world more like the earth. Recent space probes have indicated that Mars is neither like the moon nor like the earth. It has unique features of its own.

Gravity on Mars is only a third of the earth's. The land area of the red planet is more but there are no oceans. The pressure on the Martian surface is also very much less; it is equal to what prevails at 30 kilometres above the earth.

Colour Changes

One of the most fascinating features of Mars is its polar caps. They seem to retreat every Martian year. This repetitive process is intriguing. Also, when the polar cap recedes, it seems to acquire a dark colour. The south polar cap, in particular, plays hide and seek with observers.

There are also the red or orange areas, which cover most of the

surface giving it the name of a red planet. In contrast, there are irregular, dark regions, which appear blue-green and sometimes brownish. Something happens now and then to increase the contrast between the light and dark areas.

A lively controversy arose after Mariner-7 observed the polar cap in 1969. At first it was thought that it had detected gaseous methane and ammonia, which are needed for biological origin. But this view was soon discarded. The gas was identified as carbon-dioxide. It is still undecided whether the polar cap is frozen carbon-dioxide or fresh-water ice. As the pressure is very low on Mars, water can hardly remain in a liquid state. Mariner-9 has found water vapour in the atmosphere over the south polar cap.

Orange colour is associated with deserts, with some bright brick-red shades. A Soviet expert and a French astronomer hold the view that these areas are covered by a sand-like substance, called limonite.

Chaotic Terrain

Photographs taken by Mariner-9 revealed some unexpected features. There were parallel rilles extending over 1,700 kilometres areas of heavy craters, 'leopard spot' patterns of blotches and signs of deep erosion and volcanic activity'. The brightness of the blotches was found to vary. This might explain the seasonal darkening in the southern hemisphere. In sharp contrast to craters, Mariner-6 photographs revealed a featureless flat plain, smoother and larger than anything seen on the moon. A bright circular dish was found to be free of craters, though Mars is closer to the asteroid belt than the moon and meteorites collide with its surface quite often.

The chaotic terrain leads to speculation that in future, Mars may become more like the earth. There are different views on whether there were oceans on the planet in the past. For some time, people thought that there were canals for irrigation. In 1877, an Italian astronomer, Shiaparelli, thought so. What looked like canals have turned out to be an optical illusion. Soviet scientists say that pictures taken by Mars-2 and Mars-3 show no signs of any canals. They also conclude that craters of Mars are destroyed twice as fast as those of the moon, because the

presence of the thin atmosphere on the planet helps erosion. They also report that the Martian surface relief is about 300 million years old.

Even though Mars has an atmosphere, there is no nitrogen, essential for life on earth. There is very little oxygen. The original gaseous contents might have escaped because of the planet's weak gravity.

Without much air or water and with a noon temperature of 29.5 °C at the equator, it is rather puzzling how a dust storm could be kicked up to 15 kilometres at terrific speed. When the rare phenomenon of the dust-storm cleared, scientists were surprised to find cloud patterns. It has been observed that dense bright clouds drift at times towards the equator. Some scientists think that Mars is still losing water to empty space.

Since the atmosphere is thin, it lets in the ultra-violet radiation from the sun. On the earth, this radiation is blocked and life-forms are protected. Soviet biological experiments on the earth showed that Mars may have a biosphere like the earth. It was claimed that lower mushrooms and bacteria multiply in the typically Martian conditions, without any oxygen.

We cannot rule out the possibility of some life-forms on Mars, totally unknown to us, with an entirely different chemistry. There is a view that the colour changes seen on the planet are somehow associated with protective mechanism of life forms.

Testing Einstein's Theory

A unique experiment has been scheduled when Mars and earth come on nearly opposite sides of the sun. It will test a theory of the famous scientist, Albert Einstein. He said that gravitational attraction bends a light ray. This is true of radio waves too. When the radio-waves from Mariner-9 pass through the strong gravitational attraction of the sun, the expirement would see if the waves are bent by solar gravity. In that case, they have to travel a little longer distance than if they came in a straight line and arrive on earth slightly late. Scientists plan to measure the time of radio transmissions, to within less than a millionth of a second. If Einstein is right, the waves will arrive about 200 millionths of a second later than if they were travelling straight!

A Black Moon

Have you heard of a black moon? Sounds strange, but it is there. It is Phobos, one of the two mini-moons orbiting the red planet, Mars. The English novelist Jonathan Swift in his *Gulliver's Travels* said that his astronomers of Laputa discovered the two satellites of Mars. That was long before good telescopes were made but surprisingly, Swift's description of the mini-moons was quite close to what we see today with advanced instruments. More than a century later, in 1877 an American astronomer observed them. Phobos was photographed by the Mars probes, Mariner-7 and -9.

Phobos, meaning Fear, and Deimos, meaning Panic, are the smallest known satellites of the solar system. Phobos is the larger of the two. It is also the inner satellite of Mars, spinning around the planet every eleven hours; this is the only moon in the solar system that moves faster than its planet. It is only 6,000 kilometres from the surface. It is 20 kilometres wide and 25 kilometres long. Deimos is even smaller. But it rotates farther away from Mars, at a distance of 19,200 kilometres. It takes a few hours more to orbit Mars than the rotational period of the planet itself.

Phobos is the darkest body so far observed in the solar system. It has the lowest reflecting power. Only a very small portion of the light falling on its surface is reflected. It was photographed as a black dot against the surface of Mars.

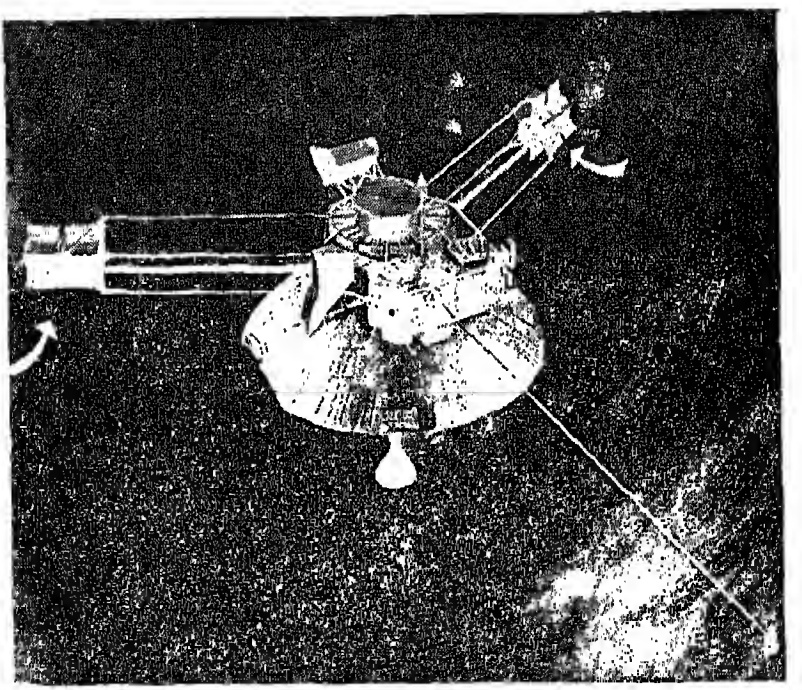
Why is it so black? One theory is, it is because of its dust-free surface. Though meteors constantly bombard its surface, dust particles would easily be swept away from it because of its weak gravity.

Where did Phobos come from? Its shape, now said to resemble a potato, suggests an answer. Since it is not a sphere, some argue that it could not come from Mars itself. In its present form, it would have been captured by Mars from the asteroid belts where such rocks abound. But the question is how a planet like Mars, with its small mass, can capture two moons. A science writer offered an unusual answer. He said Phobos is an artificial satellite, launched millions of years ago by intelligent beings on Mars. It is also claimed that Phobos is gradually slowing down, heading for destruction.

One day, Phobos could become an ideal space station for man to observe Mars. The constant meteor bombardment would of course be a problem, but protective shields could be worn. Anyone landing there should avoid jumping about as its escape velocity is very small. Any 'Kangaroo hops' like those done by the astronauts on the moon, would make one fly away from Phobos into a new orbit of Mars!

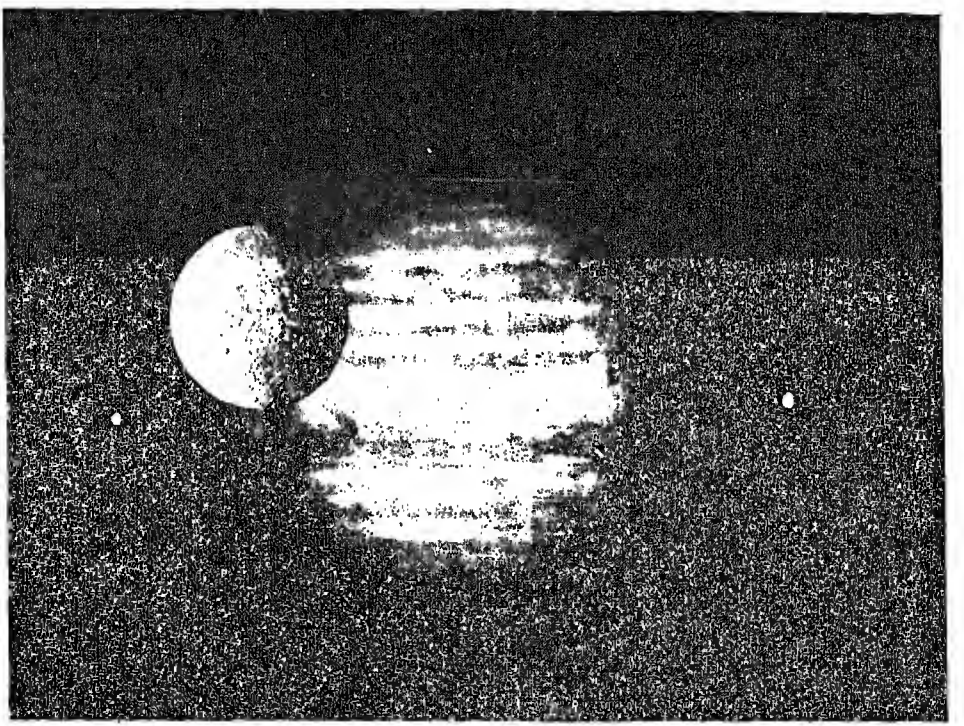
To Greet a Giant

BEYOND Mars, man will have, for the first time, a close look at the giant Jupiter, when the American Pioneer-10 spacecraft flies by it in 1973. It was launched on March 3, 1972, on a 21-month odyssey to Jupiter



Drawing of Pioneer, the U.S. Spacecraft, designed to fly past the planet Jupiter. Arrows indicate location of four radioisotope thermoelectric generators representing the first use of nuclear electric power on an interplanetary mission.

and beyond. It is expected to rendezvous with Jupiter on December 3, 1973, from a safe distance of 1,39,000 kilometres of the planet. The journey will cover 800 million kilometres. Jupiter is 2,000 times as far from the earth as the moon. The distance at its closest approach to the earth is about 576 million kilometres.



Artist's Concept of Jupiter and its Four Satellites

Pioneer-10 is the fastest man-made object. Launched by an Atlas-Centaur rocket, the 256-kg. spacecraft sped away from the earth at nearly 50,000 kmh., some 11,000 kmh. faster than any thing flown before by man. It pased the moon's orbit in about eleven hours, a journey that normally takes three days for the astronauts.

It is also the first spacecraft to make a study of the asteroid belt between the orbits of Mars and Jupiter. The belt is 150 million kilometres wide and consists of billions of pieces of rock and debris at a distance from 172 million kilometres to 552 million kilometres. The size of the pieces range from a small particle to a chunk of 772 kilometer, diameter named Ceres.

Another feature of the mission is the use of nuclear energy for the spacecraft. As it cannot get enough sunlight at great distances, solar power panels are inadequate. Hence its electrical requirements are met exclusively from four nuclear generators.

As it approaches Jupiter its speed is expected to go down to 32,180 kph. It will fly past Jupiter for four days at 79,200 kmh, before picking up a speed of 1,34,800 kmh. to escape the solar system, the first spacecraft to do so. In 11 or 12 years, it will leave our star system and enter another galaxy. Unless it is captured by another civilisation, it will wander for ever through distant galaxies. It is however expected to remain in contact with the earth until 1979 only, when it would be

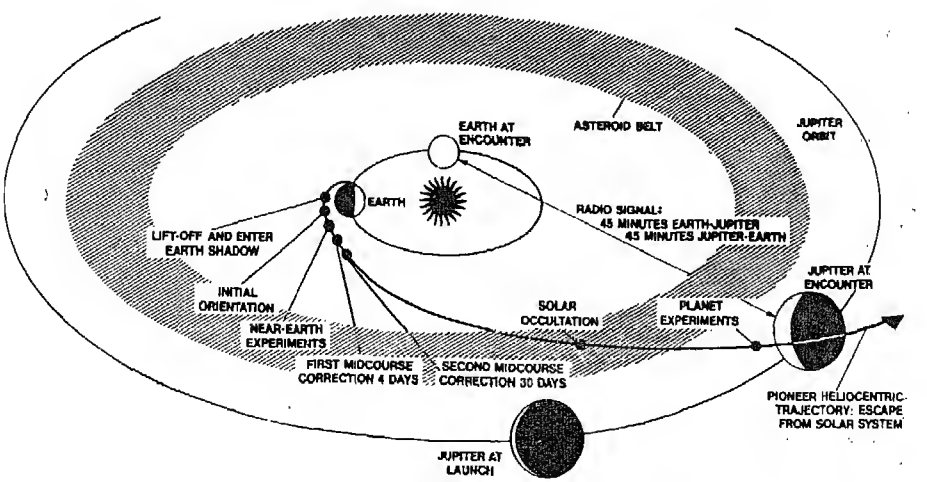


Diagram showing the flight plan of Pioneer-10

2,400 million kilometers away. Later, its radio signals would be too faint to be heard.

Jupiter is a spectacular planet. Its volume is 1,000 times that of earth and it has more than twice the mass of all the other planets combined. Its gravity pull is 300 times stronger than that of the earth. It is a colourful planet, with light and dark belts runing parallel to the equator. The main belts change in width and in intensity. Surface colours include yellow-orange to blue-grey.

Even though the planet is composed primarily of helium and hydrogen, it is believed to contain smaller amounts of the more complex gases like methane and ammonia. As the mass of Jupiter is 300 times that of the earth, its interior is subjected to terrific pressure. Under such a pressure, hydrogen will behave like metal. It is believed that Jupiter is a solid ball of hydrogen, with a cloud cover of ammonia, hydrogen, helium and other gases.

Though the temperature of the planet is cold, it is surprisingly high for a planet so far away from the sun. It has led some astronomers to say that the planet radiates more energy than it gets from the sun, implying thereby the presence of some internal heat source. Large areas below the cold cloud layer may be warm enough for life to appear.

It is also a mystery that a planet, eleven times bigger than that of the earth, should rotate more than twice as fast as the earth. A day on Jupiter lasts nine hours and 55 minutes.

A point on Jupiter's equator moves at 35,400 kmh,. compared with 1,600 kmh. on earth. The horizontal zones appear to rotate at different speeds. The outer-most belt reacts strongly to solar flares when they reach the planet.

Jupiter is a noisy planet. It broadcasts modulated radio signals of enormous power. An Australian scientist claims that the noise occurs exactly every 9 hours and 55 minutes—its period of rotation.

The most puzzling feature of the planet is its red spot, known as the eye of Jupiter. It is oval shaped, 48,000 kilometres long and 13,000 kilometers wide, big enough to cover up several earths. It may be hydrogen

ice going up and down at 30-year intervals. It appears to rotate at a different speed from that of the planet.

Extensive magnetic fields and powerful radiation belts have also been discovered around the planet. The radiation belts are estimated to be one million times more intense than the earth's Van Allen radiation belts.

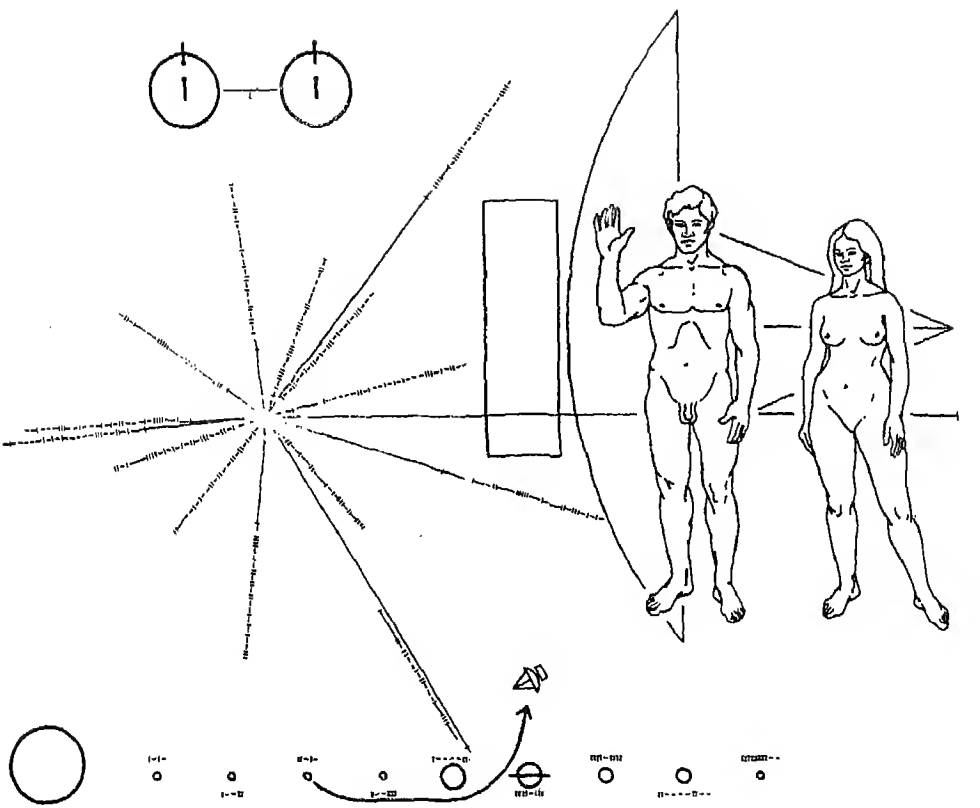
The discovery of ammonia, methane and hydrogen led many scientists to believe that Jupiter too had the same gases that were once present on the earth four thousand million years ago. Recently, a scientist, Dr. Cyril Ponnamperuma, made a replica of the atmosphere of Jupiter. He mixed ammonia and methane in a flask and introduced electric flashes. He found some basic chemicals that form amino-acids, the building blocks of life. Red colour also appeared in the flask. Dr. Ponnamperuma says life-forms on Jupiter could have made good progress.

Pioneer-10 has a 30-kg. payload of experiments. It would make 13 scientific experiments. They may provide new data on Jupiter and the outer solar system. A radio signal from its vicinity will take 45 minutes to reach the earth. The spacecraft can store five commands and function automatically. The rest of the instructions have to be radioed to it from ground control.

The experiments include twenty types of measurements of Jupiter's atmosphere, radiation belts, heat balance, magnetic field, its moons, and other features. Solar atmosphere, cosmic rays and even interstellar gas are among the other targets of study. While ultra-violet photography is used for detecting the temperature of the upper atmosphere, infra-red sensors will note the internal energy of the planet and the thermal variation in the atmosphere.

Pioneer-10 is also expected to study the inter-planetary magnetic field and measure the direction and energy of the solar wind.

On the remote chance that it might one day be intercepted by intelligent creatures of another civilisation, the spacecraft bears a gold plaque that tells in scientific symbols and drawings the time and origin of the spacecraft and the kind of people who launched it. There are figures



Greetings to an Unknown Civilisation

of a nude man and woman and the man's right hand is raised in a friendly gesture.

Saturn and Its Rings

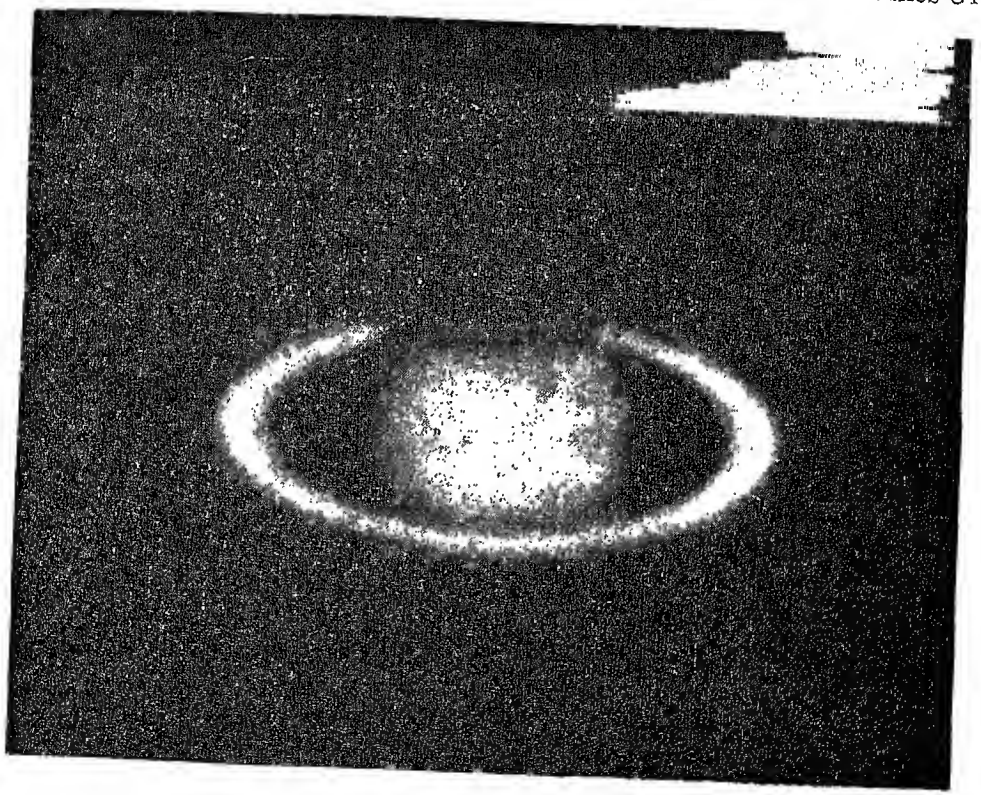
After Jupiter comes Saturn nearly as big but revolving quite far away from it. Six hundred and forty million kilometres away from Jupiter, Saturn takes 29 years to orbit the sun as against 12 years taken

by Jupiter. For a long time, it was believed that Saturn has nine moons. Recently, a tenth Moon, Janus, was discovered. A fourth ring around the planet was also reported. Saturn's rings are a puzzle. No one knows if they are frozen gas or ice-covered rock.

A Soviet observatory in Crimea claims that Saturn's atmosphere contains gaseous ammonia.

Uranus and Neptune

Beyond Saturn is Uranus. It is half the size of Saturn. It takes 84



Saturn, a recent photo taken from Kavalur

years to orbit the sun. It has five moons. Neptune which is 1600 million kilometres away from Uranus, was discovered in 1845. It has more or less the same diameter as Uranus. But it takes 165 years to go round the sun. It has two moons which circle it in opposite directions. Two scientists of the Moscow Institute of Earth Physics have suggested that outer layers of the planets would have cooled only up to 100 kilometres below their surface, since their formation five billion years ago. Taking the surface temperature of Uranus to be —173°C, they have calculated that the temperature at its centre should be as high as 26,400°C and that in Neptune 31,000° C.

Pluto

Pluto, the last planet in the solar system, is about the size of Mars. It was discovered in 1930. Unlike the gas giants, it is small. Some say that Pluto is an escaped moon of Naptune. A day on Pluto will last six earth days and nine hours. It takes the longest time to orbit the sun, 248 years. Pluto which has no moon, is 5800 million kilometres away from the sun.

Asteroids as Spaceships

A Soviet astronomer, Karl Stein, has proposed that asteroids could be used as spaceships. He believes that it would be possible to artificially change the orbits of these minor planets, by carrying out explosions on them. The comets on which explosions take place naturally, will serve as our model. Prof. Stein heads an Observatory of the Latvian University which studies the movement of 120 asteroids.

In 1968, the asteroid Icarus came within seven million kilometres of the earth. Prof. Stein said if a probe were planted on it from earth, it would have gone closer to the sun than the planet, Mercury and could have explored the solar system.

Another asteroid, named Geographos, was discovered in 1951. It is only 800 metres in diameter. In August 1994, it is expected to streak past the earth within 4,960,000 kilometres. One astronomer envisages that it can be captured and a cross-section of the civilisation could be

put on board. Landing would be simple because of low gravity. A ten-ton craft could easily be moved by a hand. It would hurl off to unknown regions and maybe, 'someone' would greet them. But there is one condition for its success. None on board should sneeze. For, the thrust from a sneeze is enough to launch one from that weak-gravity rock back into space!

A Free Ride

A unique opportunity to explore the outer planets is awaiting man. The best planetary alignment in 179 years is coming from 1976 and will last till 1980. The vintage years for launching spacecraft would be from 1977 to 1979. Then, Jupiter, Saturn, Uranus, Neptune and Pluto would line up in an unusual position. The great advantage of this alignment is the possibility of utilising the gravitational pull of one planet to bounce to another. It is a free ride in the Heavens! It would take about two years to go to Jupiter. From there, there will be a time gain. Ordinarily, it would take 14 years to go to Pluto, even when it is nearest to the earth. Now, using the gravity-bouncing technique, the journey will take only about eight years. Similarly the usual journey time of nine years to go to Neptune, will be cut by half under the new method. Automatic probes on these missions would have to depend on nuclear power source. They must also cary sophisticated self-correcting systems, as commands from earth will take a long time to reach them.

Beyond the Solar System

Once the solar system is crossed, a spacecraft will find a tenuous presence of hydrogen atoms and luminous, hazy band of stars. The nearest star is Alpha Centauri, which is over 38 trillion kilometres from the solar system. This is said to be less than the average distance between the stars. In fact, Alpha Centauri is a triplet; the largest being like the sun. The distance to this star can also be expressed in terms of light years. The distance travelled by a ray of light in one year is over nine million kilometres (at 2,97,600 kilometres a second). Alpha Centauri is thus 4.3 light years away.

Bernard's star is five light years away. It is smaller and fainter than the sun. It is a single star but in 1965, a planet was discovered revolving around it. In 1968, a second planet was discovered. Within nine light years, 30 other stars are believed to exist. Some of them are like the sun. Some of the stars, within 12 light years, where at least one planet is probable are (besides Alpha Centauri), Epsilon Eridani, Tau Ceti and, Epsilon Indi.

The Milky Way

On a clear sky, 6,000 stars have been counted. With the aid of the telescope, the number is very much more. In our cluster of stars of which the solar system is a part, there are 100 billion stars, all bound by the invisible force of gravity. This cluster is called the galaxy. The dia-

meter of the galaxy is stated to be 1,00,000 light years. The sun seems to be a minor star in the galaxy, and it is 30,000 light years away from the nucleus of the galaxy. The solar system is in one spiral arm of the galaxy. The entire system is rotating. The sun is not stationary. It goes around the galaxy once in 200 million years. The stars in our galaxy appear as a luminous band and hence it is called the Milky Way.

The Andromeda Galaxy

The closest galaxy to ours is called the Andromeda Galaxy, which is

The Andromeda Galaxy, two million light years away, resembling our own galaxy in size and shape

two million light years away from us. It resembles our own in size and shape. Its diameter is 1,30,000 light years—a little more than of our galaxy. It has also about 100 billion stars. It is faintly visible to the naked eye. The distance blurs its brilliance. Including Andromeda and the Milky Way, there are 20 galaxies, most of them smaller, forming a loose cluster.

Recently, astronomers in California detected two massive galaxies, called Maffei-1 and Maffei-2, next to our galaxy. They are believed to be three million light years away. With an enormous number of rotaing islands of stars, the galaxies seem to be large in size. Galaxies also form themselves into clusters. Three hundred million light years away, there is the Hercules group. It contains 10,000 galaxies, each with 10 billion to 100 billion stars. This is the largest system of matter in the Universe. Astronomers say that there are more than a billion galaxies. The galaxies are different in shape. Some of them are elliptical or spherical, while some are open or closed spirals.

Immense Distance

The cosmic clouds of dust and gas which sometimes hide the stars, are called nebulae. These clouds are the raw material out of which stars and galaxies are made. The Crab Nebula, the remains of a star burst in 1054 A.D., is now 42 light years across. The Virgo cluster for example is 40 million light years away. The most distant nebula is 3C 295, which is said to be at a staggering distance of six billion light years. The farther the galaxy, the greater is the speed at which it is moving away. As these galaxies are so far away, we are actually seeing them as they were, when the light from them started millions of years ago. Satellites outside our solar system may one day reveal new worlds. Space exploration is a never-ending adventure!